Department of Energy
Office of Nuclear Physics Report

on the

Annual Science and Technology Review

of the

Relativistic Heavy Ion Collider (RHIC)

July 18-20, 2007

Executive Summary

The Department of Energy (DOE) Office of Nuclear Physics (NP) held an Annual Science and Technology (S&T) Review of the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL) on July 18-20, 2007.

The RHIC Facility is a National User Facility that delivers the world's highest energy heavy ion collisions and colliding polarized proton beams for experimental research in nuclear physics. This facility has two large state-of-the-art detectors operated by the Pioneering High Energy Nuclear Interaction eXperiment (PHENIX) and Solenoidal Tracker at RHIC (STAR) research collaborations. The PHOBOS and Broad Range Hadron Magnetic Spectrometers Experiment at RHIC (BRAHMS) collaborations have ceased operations at RHIC, but they continue to analyze earlier data. Together, these experiments investigate collisions of heavy ions with the primary goal to discover and study a new state of matter called the Quark-Gluon Plasma, and collisions of polarized protons to study the internal structure of the nucleon. The RHIC facility and research staff also carry-out research and development (R&D) of advanced instrumentation, detector upgrades, state-of-the-art accelerator technology and advanced computing.

The BNL RHIC experimental and theoretical research programs continue to produce high-quality, original and creative results that advance science and technology. The spectacular success of RHIC is again demonstrated by the impressive amount of scientific measurements and publications that have appeared in refereed journals and at conferences, which continue to capture the public's interest. The panel believed that the search for the critical point on the Quantum Chromodynamic (QCD) phase diagram using low energy heavy ion beams is an important scientific opportunity that should be pursued. In summary, the RHIC research program is considered to be outstanding.

The RHIC Collider-Accelerator Division's (C-AD) performance in delivering heavy ion beams has significantly exceeded expectations. The Division's pursuit of innovative accelerator R&D is recognized world-wide. The most impressive achievement for this year was the pioneering demonstration of longitudinal stochastic cooling of heavy ion bunched beams. The C-AD staff is commended for its outstanding performance.

Stochastic cooling has the potential of increasing the RHIC luminosity. The reviewers support BNL's plan to implement stochastic cooling perpendicular to the direction of the beam on a rapid schedule. Electron cooling R&D is also a priority as it presently remains a requisite for attaining the full RHIC II luminosity goals for p+p collisions and eRHIC.

The polarization of the RHIC beam has now been measured with a precision of 4.2% compared with a goal of 5%. Measurements near the interaction point of the experiments have been made with an overall error of 9.4% again meeting the goal of 10%. This is a noteworthy achievement by the polarimetry group.

The RHIC II upgrade may be essential to realize the full potential of the spin program because of the large luminosity requirements for measuring W boson and the inclusive direct γ production. However, there were some concerns regarding the experimental sensitivity of the measurements of both the longitudinal quark spin through the decay of the W's and the direct $\gamma + X$ channels. The panel recommended that BNL develop and document a detailed plan that demonstrates the sensitivity of the proposed proton spin measurements and its impact on the run schedule between 2008 and 2013.

The Lattice Gauge Theory (LGT) effort has established itself as a preeminent resource for hot, dense QCD physics research in the U.S. The reviewers believe this leadership and the scientific impact on the RHIC program will be severely diminished should the LGT group funding not be sustained. Realizing the enormous computing resources required for LQCD calculations, BNL is asked to develop a plan for securing these resources in the context of the National Lattice Gauge Program of the USQCD collaboration.

The Nuclear Theory group has made impressive efforts aimed at performing calculations that are central to the success of the overall RHIC program. However, the reviewers think BNL has an opportunity to substantially contribute to the world-wide effort to understand the transverse spin structure of the proton, and thereby strengthen its role in pursuing this facet of strong-interaction physics. Although the 4-year plan of the Theory Group had very well laid out milestones for the spin program, it was unclear to reviewers whether the current commitment of theoretical manpower at BNL is sufficient to satisfy these ambitions. In contrast the heavy-ion program in this 4-year plan continues to have no milestones, a deficiency which should be corrected in an updated plan.

Each year the RHIC facility has continued to provide greater integrated luminosity than in previous runs. In this context, the reviewers have recommended that it is now timely for the PHENIX and STAR experiments to examine and analyze all factors that contribute to their low ratios of recorded-to-delivered integrated luminosity.

The PHENIX and STAR local groups asserted that they faced an increased burden in the form of operational tasks. Although some collaborators are migrating to the Large Hadron Collider (LHC), the availability of the workforce needed to carry out the research program, complete R&D, and construct the RHIC detector upgrades seemed to be manageable. In this regard, the newly formed A Toroidal LHC Apparatus (ATLAS) Heavy Ion group should be viewed as any other competing opportunity for resources.

The safety record of the C-AD and RHIC has continued to improve over the past ten years according to the data on performance and backward-looking indicators. The number of reportable occurrences (one in 2007) is declining towards zero. The investigation of the serious Flash Arc incident in April 2006 has been completed.

BNL management is appropriately maintaining and developing core competencies in support of the DOE Nuclear Physics Program goals. All recommendations from the previous S&T review have been addressed. Although the Mid-Term Strategic Plan identifies the facility goals leading up to the proposed luminosity upgrade, the scientific goals of RHIC II as well as the longer term scientific goals and case for eRHIC will continue to need formulation and development especially in the context of the new NSAC Long Range Plan. The eRHIC facility is considered by BNL to be a central part of the long term future of the laboratory, but it is only one of several options to realize an Electron-Ion Collider (EIC). The Mid-term strategic plan should continue to be periodically updated with broad theoretical input, especially from the laboratory. Some reviewers thought the scientific implications of the LHC heavy-ion program at CERN should to be folded in.

Funding short falls in the RHIC program were identified in several areas. Laboratory Management needs to continue its review and prioritization of funding for the experimental program and accelerator operations with respect to the distribution of R&D funding, experimental support, development of upgrades, capital equipment, in the context of projected shortfalls in the out years, ongoing efforts by the collaborations to identify additional workforce, and infrastructure needs.

DOE Recommendations

- The Pioneering High Energy Nuclear Interaction eXperiment (PHENIX) and Solenoidal Tracker at RHIC (STAR) collaborations should perform an evaluation to improve the ratio of data recorded with respect to delivered beam luminosity. All factors should be analyzed, including the efficiency of detector operations. This evaluation and planned actions should be documented in a report submitted to DOE by May 31, 2008 and presented at the 2008 Relativistic Heavy Ion Collider (RHIC) Science and Technology (S&T) review.

- Brookhaven National Laboratory (BNL) should develop and document a detailed plan with milestones that demonstrates the experimental sensitivity for the proposed proton spin measurements between 2008 and 2013 using the anticipated accelerator design capabilities and detector performance as a planning base. This plan should be submitted to DOE NP by May 31, 2008 and presented at the 2008 RHIC S&T Review.

- Considering the magnitude of the resources required for the lattice gauge calculations envisioned by the Lattice Gauge Theory (LGT) group, RHIC should develop a plan for obtaining the computational capabilities to realize the scientific goals. This plan should be developed in the context of the National Lattice Gauge Program of the U.S. Quantum Chromo Dynamics (USQCD) collaboration, submitted to the Department of Energy (DOE) Office of Nuclear Physics (NP) by May 31, 2008 and presented at the 2008 RHIC S&T review.

- BNL should develop a plan with an aggressive schedule to demonstrate feasibility of transverse and longitudinal cooling with bunched beams. This plan should be submitted to DOE by December 31, 2007.

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Introduction

On July 18-20, 2007 the Director of the Facilities and Project Management Division of the Office of Nuclear Physics (NP) performed a Science and Technology (S&T) Review of the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL) in Upton, New York.

The review committee consisted of seven external consultants: Dr. Peter Barnes (Los Alamos National Laboratory), Dr. Charles Prescott (Stanford Linear Accelerator Center), Dr. Jean-Pierre Delahaye (European Organization for Nuclear Research), Dr. Harold Jackson (Argonne National Laboratory), Dr. David Richards (Thomas Jefferson National Laboratory), Professor George Fai (Kent State University), Dr. Gerhard Mallot (European Organization for Nuclear Research) and Profesor Sergei Voloshin (Wayne State University). The review was chaired by Dr. Gulshan Rai, Program Manager for Heavy Ion Nuclear Physics. Dr. Dennis Kovar, Asssociate Director of the Office of Science for NP; Dr. Jehanne Simon-Gillo, Director of the Facilities and Project Management Division for NP; Dr. Brad Tippens, Program manager for Medium Energy Nuclear Physics for NP; Dr. Sidney Coon, Program Manager for Nuclear Theory for NP; Dr. Helmut Marsiske, Program Manager for Instrumentation for NP; and Dr. Manouchehr Farkhondeh, Program Manager for Advanced Technology Research and Development for NP attended as well.

The primary purpose of the annual S&T review is to evaluate the quality, performance, and significance of the ongoing and planned RHIC programs, in the context of the Nuclear Science Advisory Committee (NSAC) Long Range Plan for Nuclear Science and the national nuclear physics program. In order to perform the review, each consultant was asked to evaluate and comment on any relevant aspect of the science and technology at the RHIC, facility operations and strategic planning. Specifically, the focus of the Science and Technology Review was on understanding:

- The quality, productivity, and significance of the laboratory's scientific and technical accomplishments and the merit, feasibility and impact of its future planned physics program;

- The effectiveness and appropriateness of facility operations and the planning for future facility upgrades in support of the research program;

- The effectiveness of management in strategic planning, developing appropriate core competencies, implementing a prioritized and optimized program, and promoting and implementing a safe work environment;

- The leadership, creativity, and productivity of the facility's scientific and technical staff in carrying out the above activities; and

- The quality and appropriateness of the laboratory's interactions with, and nurturing of, its scientific community.

In addressing these charge elements, the reviewers were also asked to comment on what progress had been made towards addressing action items from the previous S&T Review, and on the facility's computing capabilities, both current and planned. Prior to the review, BNL had provided background material to the panel reviewers, including copies of the 2006 RHIC S&T Report, the Response from RHIC regarding the 2006 S&T DOE Recommendations, and an updated Mid-Term Strategic Plan.

The review was based on formal presentations given by the RHIC operations and research staff, detailed discussions with the staff, and the panel members' extensive experience. The first day was devoted to plenary presentations on science, facility operations and planned upgrade projects for both instrumentation and the accelerator. The second day commenced with breakout sessions that focused on RHIC accelerator performance and operations, progress on RHIC beam Stochastic cooling, accelerator research and development (R&D), RHIC Computing Facility (RCF) operations and the BNL groups' contributions to the RHIC scientific program. Question and answer sessions and executive sessions were held throughout the review. A verbal briefing of preliminary findings, comments and recommendations was presented to Dr. Peter Bond, Acting Associate Laboratory Director for Nuclear and Particle Physics, and other BNL staff upon the conclusion of the review on the third day. The panel members were asked to submit their individual evaluations and findings in a "letter report" covering all aspects of the RHIC program. The executive summary and the accompanying recommendations are based largely on the information contained in these letters reports. Appendix A lists the recommendations from the 2006 RHIC S&T Report and their current status. A copy of the charge letter and the agenda are included in Appendix B and Appendix C, respectively.

Scientific Program

Experimental Heavy-Ion Research Program

Findings:

RHIC is the world's premier heavy-ion and polarized proton collider facility, which has now operated for seven years. The latest studies of the strongly interacting Quark Gluon Plasma (sQGP) through measurements of collective flow and jet behavior in the core of nuclear collisions continue to stimulate worldwide interest. The surprising finding that the quark-gluon plasma behaves like an almost perfect fluid was highlighted in the May 2006 Scientific American publication. Last year, the RHIC experiments have published 53 refereed papers (132 papers to date) in scientific journals and awarded 25 Ph.D. degrees.

Scientific and technical achievements during the last year, in which the BNL staff played a major role, included:

- The observation of high p_t π^0 suppression and non-suppression of the direct gammas except at very high transverse momenta (PHENIX);
- The detailed study of particle production, jet quenching, and anisotropic flow vs. system size and collision energy (STAR, PHENIX, PHOBOS, and BRAHMS);
- The measurement of Jet and background event modification via two and three particle correlations (STAR and PHENIX);
- The first measurement of excess of low mass di-leptons (PHENIX); and
- The study of electron tagged D^0 correlations utilizing electron trigger (STAR).

The two large RHIC experiments, Pioneering High Energy Nuclear Interaction eXperiment (PHENIX) and Solenoidal Tracker at RHIC (STAR) presented plans for future detector upgrades with an emphasis on measuring "rare" probes. Both these experiments have begun a period of detector upgrades while the two smaller experiments, Broad Range Hadron Magnetic Spectrometers Experiment (BRAHMS) and Phobos, have completed their experiments. Some BNL researchers affiliated with the two erstwhile experiments have joined the PHENIX and STAR collaboration, while others have proposed to initiate an effort to study heavy-ion collisions at the Large Hadron Collider (LHC) with the A Toroidal LHC Apparatus (ATLAS) detector.

During Run 7, PHENIX has recorded 813 μb^{-1} integrated luminosity (3.4 x Run 4). STAR met its goals for recorded number of events with an effective recorded luminosity of 600μb^{-1}. The recorded-to-delivered luminosity ratio for both collaborations is in the range of ~0.2-0.4.

PHENIX and STAR Collaborations had expressed concerns about the increasing load on the local BNL groups for detector maintenance and operations support.

Comments:

The overall RHIC research program is considered to be outstanding. The results produced by the program continue to provide deeper insights changed into the strongly interacting quark-gluon plasma and its properties. The most recently completed run devoted to Gold beam collisions was considered by all the panel reviewers to be very successful both for facility operations and the unprecedented amount of data collected. The RHIC staff and the experiments are to be commended.

The panel reaffirmed the merits of the BNL mid-term strategic plan for future detector upgrades and potential new opportunities afforded by the RHIC luminosity upgrades. The panel also believed that the search for the critical point on the quantum chromo dynamics (QCD) phase transition diagram using low-energy heavy-ion beams is an important scientific opportunity that should be pursued.

The discovery of the sQGP from signatures of strong collective flow and dramatic jet quenching is viewed as a milestone in heavy-ion physics. Other significant achievements of the RHIC program in the past year include the detailed comparison of high p_t suppression data with theory which has allowed a quantitative estimate of transport properties of the medium, such as jet energy loss. Flow fluctuation results have provided new information on initial conditions which might support the Color Glass Condensate (CGC) picture. The suppression and flow of heavy quarks appear to indicate a small relaxation time and small viscosity of the sQGP medium, while the few particle correlation study of jet interaction with the medium could open new possibilities to characterize the properties of hot, dense nuclear matter.

A significant effort of the STAR Collaboration has been invested into the recalibration and software development of the silicon trackers that promises new results on open charm production from the reprocessing of Cu+Cu data and the Run 7 data. Regarding STAR's future plans, the reviewers strongly encouraged the collaboration and BNL management to complete the upgrade of STAR's Data Acquisition 1000 (DAQ1000) - a critical subsystem that will be needed for Run 9 and beyond.

The experimental search for the QCD critical point tentatively scheduled for Run 10 is considered a worthy and an important milestone by the reviewers. This year, the RHIC facility delivered heavy ion collisions at energies well below the top CERN SPS energy. This success bodes well for future beam development, but some reviewers thought the specific measurements of the low energy beam scan at RHIC needed to be articulated and detailed plans developed by the PHENIX and STAR collaborations. Both experiments should present well-formulated plans in their Beam Use Proposals and to the RHIC Program Advisory Committee (PAC).

The RHIC facility has continued to provide greater integrated luminosity per run for a given type of beam ion than in previous runs. The Gold beam luminosity has exceeded the accelerator design goals and recent new developments on bunched-beam stochastic cooling reported at this review suggested that beam lifetime and thus integrated luminosity could be further enhanced in the future. In this context, the reviewers

believe it is timely and important for the PHENIX and STAR experiments to examine and analyze all factors that contribute to their low ratios of recorded-to-delivered integrated beam luminosity.

Recommendations:

- The PHENIX and STAR collaborations should perform an evaluation to improve the ratio of data recorded with respect to delivered beam luminosity. All factors should be analyzed, including the efficiency of detector operations. This evaluation and planned actions should be documented in a report submitted to DOE by May 31, 2008 and presented at the 2008 RHIC S&T Review.

Experimental Spin Research Program and Polarization Physics

Findings:

RHIC is the world's first and only polarized proton collider dedicated to understanding the origin of the nucleon's intrinsic spin. As reported in the previous S&T review, the 2006 polarized proton run was very productive. Integrated luminosity had tripled and polarization increased from 46% to 60%, yielding an improvement in the figure of merit by approximately a factor of 9. This technical progress is now reflected in the precision of the latest A_{LL} data for π^0 production by PHENIX and the projected precision of the STAR A_{LL} jet data. These measurements address a specific 2008 NSAC milestone.

In the 2005 run, the average polarization of the RHIC beam has been measured with a precision of 4.2% compared with a goal of 5%. This results in an uncertainty of 9.4% in the double spin asymmetry that include corrections for effects of the profile of the proton beam polarization, again meeting the goal of 10%.

The RHIC program has begun addressing the contribution by the gluons to nucleon spin. Preliminary studies of double spin asymmetries of the neutral pion production at large pt suggest a somewhat smaller than expected small gluon polarization (i.e. measurement of A_{LL}) contribution to the nucleon spin.

RHIC has outlined a spin-physics program to obtain further information on the gluon polarization in the nucleon, for example through direct-photon production, and a program to determine the flavor dependence of the parton distributions through $W^{+/-}$ production.

Transverse Single-Spin Asymmetries (i.e. measurement of A_N) could probe for orbital motion of quarks within transversely polarized protons. QCD theory predicts very small $A_N \sim 10^{-3}$ transverse SSA for particles produced by hard scattering collisions. Fermilab experiments have observed large transverse SSA effects in polarized proton collisions at $\sqrt{s} = 20$ GeV. Two explanations for these large SSA have been proposed: the Collins and the Sivers mechanisms. The Sivers mechanism requires quark orbital

motion and thus SSA should be present for a jet and γ (photon) final state. However, experiments are needed to separate the Collins and Sivers contributions.

RHIC experiments (BRAHMS, STAR and PHENIX) have recently measured SSA transverse spin effects in π production. The Feynman x_F dependence of large-rapidity pion production shows large transverse SSA at RHIC energies which persist with similar characteristics over an energy range of $20 < \sqrt{s} < 200$ GeV. However, the direct measurement of the Sivers effect via mid-rapidity di-jet A_N using Run 6 data appear to be consistent with zero and an order of magnitude smaller than asymmetries seen in semi-inclusive Deep Inelastic Scattering (DIS) by HERMES.

Comments:

The 2006 accelerator performance at 100 GeV and the first data emerging from this run are outstanding. RHIC performance has surpassed the design values for p+p collisions by a factor of five, although a factor of three in luminosity is missing to reach the enhanced design values, which appeared to the reviewers to be difficult to achieve.

The first effort to accelerate polarized protons to 250 GeV reached a polarization of ~45%. Reaching the goal of 70% at the enhanced luminosity of 1.5×10^{32} cm^{-2} s^{-1} is a substantial challenge, but no outstanding technical issues have emerged that would preclude reaching the design polarization of 70% at the full enhanced goal luminosity.

Determining the beam polarization accurately has been a long standing priority at RHIC. A dedicated group of experts from the PHENIX and STAR collaborations and the BNL Collider Accelerator Department (CA-D) have organized themselves into a polarimetry group committed to providing the data required to satisfy the RHIC accelerator and detector needs. While the group has achieved their polarimetry goals, some of the proposed spin asymmetry measurements may require better than 10% accuracy on beam polarization at the experimental intersection points.

The RHIC A_{LL} data presented at this review appear to challenge the gluon polarization $\Delta G / G$ obtained from inclusive Deep Inelastic Scattering (DIS) and thus RHIC data could have a strong impact on resolving the long standing puzzle of the polarization of gluons in the nucleon. The excellent agreement of the NLO calculations of perturbative QCD with the observed cross-sections ensures that the data can be analyzed in terms of the gluon polarization $\Delta G / G$. However, the interpretation is apparently clouded by the lack of resolution in x_{bj} and large sensitivity to the shape of the gluon polarization distribution. Progress in this area will require second generation measurements of different channels, e.g. di-jet production at varied kinematics. The reviewers believe the feasibility of the most promising reaction channel, i.e. the direct photon production, should be demonstrated and pursued at the earliest opportunity.

Transverse spin asymmetries potentially manifest the partonic orbital motion within the nucleon, and therefore, they are the focus of present theoretical and experimental efforts. However, higher precision data with extended kinematic range will be needed

to see to what extent the p_T transverse-momentum dependence deviates from expectations. The Sivers asymmetries can be linked in a model-dependent way to orbital angular momentum, while the flavor dependence of the parton distributions may be determined through $W^{+/-}$ production. These evolving interests are exciting areas of future research, but they also raise theoretical as well as experimental challenges. The reviewers think BNL has an opportunity to substantially contribute to the world-wide effort to understand the transverse spin structure of the proton, and thereby strengthen its leading role in pursuing this facet of strong-interaction physics.

The RHIC II upgrade may be essential to the realization of the full potential of the spin program because of the large luminosity requirements for W and direct photon production. However, the reviewers believed a detailed "management" plan for both PHENIX and STAR experiments are needed for the second generation of measurements of the proton spin program because the experimental sensitivity to these measurements has not been demonstrated.

Recommendations:

- BNL should develop and document a detailed plan with milestones that demonstrates the experimental sensitivity for the proposed proton spin measurements between 2008 and 2013 using the anticipated accelerator design capabilities and detector performance as a planning base. This plan should be submitted to DOE NP by May 31, 2008 and presented at the next annual RHIC S&T Review.

Theory Program

Findings:

The RHIC theory program includes two defined groups, the Nuclear Theory (NT) group and the relatively new Lattice Gauge Theory (LGT) group. Both groups work in close collaboration with the RIKEN-BNL Research Center, a joint center of Rikagaku Kenkyusho (RIKEN, The Institute of Physical and Chemical Research) and Brookhaven National Laboratory (BNL). The efforts of the two groups together encompass the three manifestations of QCD explored at RHIC: QCD of bulk matter at finite density and temperature, QCD at small x, and the QCD origin of the spin of the nucleon.

The NT group is comprised of 7 senior members and two postdocs; 7 full-time equivalents (FTE) are funded by the Nuclear Physics program. One senior member concentrates on perturbative QCD studies of the origin of the spin of the nucleon, one senior member provides theoretical support to the worldwide hypernuclear program and the remainder study aspects of relativistic heavy-ion collisions. The LTG group presently consists of three senior members and four postdocs. The Lattice Gauge Theory program is primarily funded by the laboratory, with some Laboratory-Directed Research and Development (LDRD) support ending in 2008.

Since last year, the NT group has performed work on relating the mechanisms for single spin-asymmetries in Drell-Yan and on ruling-out the gluon spin contribution to nucleon based the so called "GRSV-standard" parton distribution. To quantify the "fit" with the different GSRV expectations and the data, the collaboration of PHENIX and the NT group established confidence levels. These exclude GSRV-standard ($\Delta G=0.4$) scenario and the confidence are essentially zero for the two expectations of GSRV based on either large positive or negative gluon polarizations. On the heavy-ion side, the group has obtained the first derivation of a Glasma kinetic equation, and investigated the role of initial conditions on the viscosity of sQGP. The phase diagram of QCD has been investigated qualitatively in the limit of large-Nc. These activities are in direct support of the experimental program.

The LGT group is exploring the phase structure of QCD through lattice calculations. These calculations are done on the DOE funded QCDOC, the RIKEN funded QCDOC, the Blue Gene/L at LLNL, and an apeNEXT in Germany. A comparison of lattice quarkonium correlation functions with those constructed using potential models indicates the melting of all charmonium states close to the critical temperature. A precise computation has been made of the zero baryon density equation-of-state (EoS) which is used for hydro-dynamical simulations. At small non-zero chemical potential, the quark-number susceptibilities have been obtained with consistency among different lattice discretizations. These susceptibilities are related to the leading order corrections to the pressure as one goes from zero chemical potential to small non-zero values.

Members of the NT group have used quenched EoS results from the Lattice Group to show that close to the deconfinement temperature Tc the bulk viscosity of the strongly-interacting QGP becomes large with a viscosity-to-entropy ratio $\zeta/s \simeq 1$. This result suggests the dominance of bulk viscosity over the shear viscosity η, assuming that η/s is not much higher than the conjectured bound of $1/4\pi$ near Tc. The calculation in full QCD is continuing.

The New York Blue/Blue Gene L machine is a powerful resource for lattice calculations; for example a presented future calculation on this machine will need ~5 TFlops-years, a number comparable to the ~ 9 TFlops-years delivered in 2007 of the SC Lattice Major IT investment. A program for computations of lattice QCD thermodynamics with petaflops resources was presented by the RIKEN-BNL-Columbia petaflops initiative.

The Mid-Term Strategic Plan (updated shortly before this S&T review) and a document presenting the status and prospects for the RHIC spin-physics program was prepared as input to the 2007 Nuclear Physics Long Range Plan. Both these documents acknowledged the role of Theory to the success of the program, and included Theory-Group members in their preparation. In addition, a research plan for theory was prepared following the 2005 S&T review.

Comments:

The reviewers believe the two (NT and LGT) groups have made impressive efforts aimed at performing calculations that are central to the success of the overall RHIC program. The reviewers highlighted several accomplishments. In particular, the NT Group has shown that Color Glass Condensate (CGC) initial conditions imply viscous effects are needed for a successful description of measured elliptic flow within a hydrodynamics-cascade picture. The investigation of the phase structure in large-Nc reveals the possibility of a confined, chirally symmetric phase. The perturbative QCD work is closely integrated with the experimental spin program and it has significantly contributed to the understanding of the origin of nucleon spin. The concepts of the CGC are largely attributed to members of the BNL and RIKEN. The recently established Lattice Gauge Theory group has a world-leading reputation in the study of QCD at finite temperature and density, and this leadership is reflected in the number of invited talks at the major international conferences.

The collaboration with the RIKEN-BNL Research Center is recognized as being very valuable and highly productive. The reviewers suggested that future theory presentations at the S&T reviews should articulate this synergy.

The research plan of the NT Group in the period 2006-2010 was presented in a document prepared following the 2005 S&T review; this plan is focused on enabling the achievement of the appropriate NSAC performance milestones, and specifically on calculations in support of the RHIC program. The "spin" component of this document contains a very concrete timeline of computations in support of the program in tabular form, and a similarly concise tabulation for the other components of theory research would be valuable. In the absence of such a tabulation, the extent to which the BNL theory group as a whole is integrated into the overall RHIC program remained unclear to some reviewers. BNL should explore ways in which the broad theory personnel can better reinforce the scientific goals of the facility and the phenomenological bridges to the experimental data. As a first step, the reviewers indicated BNL should incorporate its updated Nuclear Theory Research Plan into both the Mid-Term Strategic Plan updates and into the RHIC-spin updates.

The proposed scientific program of the Lattice Gauge Theory program is compelling and important for the interpretation of RHIC results. The accomplishments of the LGT group are of outstanding quality. The reviewers believe this leadership and the scientific impact on the RHIC program will be severely diminished should the LGT group funding not be sustained.

The exploitation of the lattice results for the experimental program often involves additional theoretical work beyond the lattice calculations themselves. Lattice Gauge calculations typically study the static, equilibrium properties of QCD at finite temperature and density, and thus cannot confront experiment directly without additional theoretical and phenomenological effort. The benefits of such work were

demonstrated in this year's combined effort by the Lattice and Theory Groups on bulk viscosity of the sQGP. Such an integrated effort was viewed very positively and the reviewers encouraged further developments in this direction.

The RHIC spin community has identified an ambitious experimental program requiring strong phenomenological support to be realized; it was unclear to the reviewers whether the current commitment of theoretical workforce (one senior staff member) at BNL is sufficient to satisfy these ambitions. The LGT group has outlined a program of future computations that are ambitious and integral to the finite-temperature/heavy-ion program. Similarly, the reviewers advised the RHIC-spin program will require commensurate lattice calculations to attain the greatest impact. These calculations are not presently envisaged by the LGT group.

Even so, the realization of LGT research plans as presented depends on the availability of enormous computational resources in the near term future. The USQCD collaboration has been working with the Office of Science for eight years to develop the computational infrastructure needed for lattice QCD studies in particle physics and nuclear science. Infrastructure in place and used by nearly all lattice physicists in the U.S. includes the DOE funded QCDOC at BNL, currently a part of the SC Lattice Major IT investment and managed by DOE and the Lattice QCD Executive Committee. Although the LGT group is a dominant part of the national lattice effort it is not represented on the Lattice QCD Executive Committee. BNL may wish to better integrate this very successful and ambitious LGT group into the national lattice effort.

Recommendations:

- Considering the magnitude of the resources required for the lattice gauge calculations envisioned by the LGT group, RHIC should develop a plan for obtaining the computational capabilities to realize the scientific goals. This plan should be developed in the context of the National Lattice Gauge Program of the USQCD collaboration, submitted to DOE NP by May 31, 2008 and presented at the 2008 RHIC S&T review.

RHIC Computing

Findings:

Resource utilization in RHIC Computing Facility (RCF) had improved in 2007 (from about 62% to 77%) as a result of addressing the issues as brought up in the 2006 S&T review. Estimates were made by PHENIX, RCF and STAR of the computing resources required to meet their projected needs and reported as part of the updated Mid-Term Strategic plan for 2006-2011. The expected computer processing unit (CPU) capacity growth for the RHIC Computing Facility (RCF) was presented as

steadily evolving from 2.8 MSI2k[1] in FY 2007 to ~28 MSI2k in FY 2011, while total disk space increasing from 920 TB (terabytes or 10^{12} bytes) in FY 2007 to 6,580 TB in FY 2011. The latter growth in demand for online disk storage exceeds the CPU costs. Both PHENIX and STAR also make use of non-RCF computing resources on a large scale.

The deployment of disk technology is differentiated by function, namely, the limited "full function" central disk for read/write application and the extensive, but mostly "read-only" distributed disk. The full function disks provide high performance and high availability and thus have stringent performance requirements. In early 2007, many service disruptions were reported due to old and unreliable equipment and services distributed on too many different products. Consequently, RCF initiated a storage evaluation project which scrutinized and tested vendor products for demanding performance and resilience requirements. As a result, RCF is planning to purchase with FY 2007 funds a 200 TB disk system from BlueArc/Hitachi to replace equipment older than 3 years. The High Performance Mass Storage System (HPSS) has a storage capacity of 7 PB (petabytes = 10^3 TB) and currently holds 5.5 PB of data. The physical building infrastructure of the RCF is close to reaching its capacity and floor space. Space cooling is exasperated by the needs of other non-RCF co-located equipment. The historical annual replacement of RCF equipment at the level ~ $2 million/year has not been possible in the past two years.

In terms of accomplishments, the RCF has recorded 800 TB of data in Run 7. PHENIX experiment's archive rate (300 megabytes/sec) has surpassed the projected rates for the CMS (Compact Muon Solenoid) and ATLAS experiments at the CERN LHC; only the ALICE heavy ion experiment is projected to have a higher archive rate.

A 100 teraflop, BlueGene/L supercomputer provided by New York State is in place at RCF. Code named New York Blue (NYB); it currently ranks #5 in the world and is intended for use by several programs and institutions. However, operating funds were not provided to support the New York Blue, though two years of hardware maintenance is being supported by International Business Machines (IBM) Corporation. The operation of New York Blue places considerable additional demands on existing infrastructure that could negatively impact the RHIC Computing Facility.

Comments:

The reviewers are in agreement with the BNL management that the physical infrastructure requires immediate attention. Available floor space needs to be increased by 2008 (and further beyond 2009) and the cooling problems need to be solved.

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[1] SPECINT2000 (1 unit = SI2k, 10^6 SI2k = MSI2k) is a computer benchmark specification for CPU's (Central Processing Unit), integer processing power. It is maintained by the Standard Performance Evaluation Corporation (SPEC).

Given the plan for the projected experimental needs, the annual replacement of hardware at the 25% level at RCF appeared to be reasonable to the reviewers. However, the RCF plan should be updated annually due to reflect the changing RHIC run schedule, timing of the detector upgrades, off-site resources and the technology performance advancements. A comprehensive approach is necessary to determine the holistic needs of the PHENIX and STAR experiments, as well as to examine the adequacy of "off-site" resources and the efficiency and cost effectiveness of the existing computing framework. For example, RCF could consider the establishment of an external committee to periodically evaluate the data storage effectiveness, efficient usage of RCF resources and computing needs of the RHIC experiments.

RCF resource utilization was a problem pointed out in last year's S&T Review (~ 62%), and has been successfully addressed since then, improving to ~77% in Run 7. This was achieved by making idle cycles available to "guest" users, but evicting them when the "owner" experiment needs cycles. It appeared that when a "guest" was "evicted", a loss of the job resulted. Scheduling refinements that allow guest jobs to complete in some way should be investigated.

The New York Blue (NYB) supercomputer while currently in place at the RCF has impacted the facility's cooling and power requirements. BNL should carefully evaluate the operating costs for NYB including its own infrastructure needs. BNL indicated that it was in the midst of negotiations to secure non-DOE NP operating funds. These negotiations need to be concluded quickly.

Recommendation:

- None

Facility Operations and Planning for Future Facility Upgrades

Operations

Findings:

The RHIC accelerator complex of 7 coupled accelerators is a unique facility providing heavy ion collisions and polarized p-p collisions. Many performance goals have been met or surpassed:

- Luminosity of 12 x 10^{26} cm^{-2} s^{-1} with Au+Au collisions was achieved during the RHIC 2007 run that is 50% above the enhanced design goal of 8x10^{26} cm^{-2} s^{-1} foreseen for the 2009 run;
- Luminosity of 20 x 10^{30} cm^{-2} s^{-1} with p+p collisions at 200 GeV achieved during the RHIC 06 run exceeded projections and is a factor of 3 below the enhanced design goal of 60 x 10^{30} cm^{-2} s^{-1} at 200 GeV (150 x 10^{30} cm^{-2} s^{-1} at 500 GeV);
- Achieved polarization of ~60% at 200 GeV is very close to the enhanced design goal of 70% foreseen for 2009 and 45% was already achieved in a first test at 500 GeV.

Present limitations of achieving the proton beam enhanced luminosity design goal and the proton polarization have been identified after actions have already been taken to improve performance. Plans have been presented to reach enhanced design goals by 2009.

An integrated luminosity goal of 3300 μb^{-1} (inverse microbarn) was achieved during run 7 in spite of the 46% time in store (goal 60%) and a somewhat degraded machine reliability to ~70 % (goal of 80%), primarily due to power supply failures.

The C-AD has completed a risk analysis of proposed Capital Equipment (CE) projects and Accelerator Improvement Projects (AIP) both in terms of downtime and performance, addressing major issues over a period of approximately five years and eliminating single point failures. BNL proposes that funding at approximately $5 million per year without redirection towards the Electron Beam Ion Source (EBIS) is needed to implement the plan. The total accelerator-wide system upgrades were estimated to cost ~$23 million to complete.

The C-AD staff has invested approximately $7.7 million in fiscal year (FY) 2007 in accelerator research and development (R&D) efforts aimed primarily at electron cooling, stochastic cooling, furnishing an electron beam for eA and polarized ep physics at RHIC (eRHIC) and machine operations development.

The C-AD is currently fabricating the EBIS to replace the tandem accelerator injector source that will lead to more cost-effective RHIC operations. EBIS utilizes a superconducting ion trapping technology to generate a pulsed ion source and provides

opportunities for new capabilities, including U and polarized He^3. In the longer-term, two major upgrades of the facility are being pursued, RHIC II and eRHIC, which are dependent on significant R&D programs.

An Energy Recovery Linac (ERL) is an essential component in an e-cooling facility that could provide higher luminosity heavy ion and p-p collisions in RHIC II. The plan is to demonstrate energy recovery in a single loop ring with a SC RF at 20 MeV. The ERL requires a second loop running at 54 MeV, plus a non-magnetic straight section, additional SC rf, turnarounds, an Superconducting Radio Frequency (SRF) gun, and beam transport sections. The R&D ERL was presented as being on track for start of commissioning in February 2009.

The electron-cooling R&D program is jointly supported by the Department of Energy, DOE NP and the Department of the Navy. The Navy has provided ~$1.8 million in direct and ~$0.8 million in kind to the ~$2 million R&D funds from DOE NP. The achievement of the Navy goals is dependent on continued DOE NP support.

Stochastic cooling of bunched beams is a recent concept developed by RHIC staff that could offer a cost effective and timely path to beam cooling and optimized performance of RHIC on a fast track. Longitudinal stochastic cooling of one beam has been demonstrated this year and is planned to be operational in the Yellow Ring next year, providing Inter-Beam Scattering (IBS) compensation and HI beam life-time improvement. Implementation in the Blue Ring will then be started.

Stochastic cooling with bunched beams could improve the HI performance at relatively low cost if transverse cooling of bunched beams is demonstrated. A luminosity of 50 x 10^{26} cm^{-2} s^{-1} with Au+Au is predicted. These developments are not applicable to p+p collisions because of the high density of particles per bunch. The schedule for transverse cooling R&D is currently aiming for a 2009 demonstration, although an accelerated schedule is being considered.

eRHIC is being considered as a future facility to study 5-20 GeV polarized electrons on polarized p, polarized He-3, and Au collisions at the highest energies possible. A linac-ring design is preferred over a ring-ring design and e-cooling is essential for the overall performance. R&D towards a possible electron ion collider has been recommended by the Nuclear Science Advisory Committee (NSAC) in the new Long Range Plan (LRP) process.

A polarized gun at 250 mA current is required for the eRHIC design luminosity of $1x10^{34}$ cm^{-2} s^{-1}. This current far exceeds existing capabilities for polarized guns. The Massachusetts Institute for Technology (MIT) has proposed and is being funded to conduct an R&D program to develop this capability.

Comments:

The C-AD is to be congratulated for continuing to exceed machine performance goals and for innovative technological developments which improve machine performance,

particularly in the recent achievements of stochastic cooling. The C-AD is congratulated for having successfully started construction of the EBIS and adhering to project cost and schedule plans.

The C-AD has conducted an analysis that demonstrates comprehension of the present limitations of machine performances. The plans to further improve performance towards the enhanced design goals by 2009 are appropriate and comprehensive.

The polarization design goal of 70% in the AGS and 100% polarization transmission efficiency at 500 GeV appeared feasible to the experts on the S&T panel. A concern remained that a factor of three improvement in luminosity is still needed for p+p collisions in spite of efforts to reduce beam-beam effects. The planned beam studies on possible increases of bunch charge and Beta* reduction are strongly supported by the reviewers.

Beam time in store (46%), together with degraded reliability, has limited the time for physics to 30% of the total run time. Reliability of ageing equipment has the potential to limit the productivity of RHIC. The panel recognized that BNL management is giving high priority to reliability of operations, but some still find the Risk Assessment difficult to understand and the connection between risk and priority unclear. Overall, the reviewers feel RHIC management has presented a reasonably complete evaluation of the risks that could potentially degrade the accelerator downtime and performance together with an analysis of the AIP and CE funds needed to address these risks.

Considerable progress on the Energy Recovering Linac (ERL) R&D was evident to the reviewers. The claimed feasibility of electron cooling is based on theory input, simulations, experience on earlier coolers, and R&D on components. The SRF gun has high technical risk. The reviewers indicated other technical options (e.g. a normal conducting gun) are available and these should be considered. In light of the technical risks, the reviewers think confidence in the simulations should be taken cautiously in claiming feasibility, and that it is important to proceed with the technical demonstration.

The necessity for development of Super-Conducting (SC) expertise and installation of facilities for the fabrication and tests of SC cavities as a core activity at BNL must be carefully evaluated in view of the duplication of effort and investments involved, including materials and specialized workforce.

The credibility of the present design concept for eRHIC which relies on an unprecedented extrapolation of polarized source performance will have to be established. The reviewers think it might be prudent to present a concept with more realistic capability.

The reviewers recognized the demonstration of longitudinal stochastic cooling in the "Yellow" RHIC ring as an outstanding achievement and significant development for RHIC. This technique was used successfully at CERN and at the Fermilab, but the

bunched, heavy ion beams at RHIC presented new challenges. Thus, it is the first time stochastic cooling has been achieved on a bunched beam and this offers the potential for a significant increase in luminosity for RHIC. A full system of longitudinal and transverse cooling in two rings could increase the heavy ion luminosity by a factor of 4. The R&D for transverse cooling will requires considerable further work and new components. Location of the pickups is still an open question, and vacuum vessels for the transverse kickers need to be designed. The reviewers think it may be necessary to have pickups in the cold sections, which would present yet a new challenge. Nevertheless, the S&T panel supported the development of an aggressive plan to equip the Yellow ring with at least one plane for implementing transverse stochastic cooling.

Recommendations:

- BNL should develop a plan with an aggressive schedule to demonstrate feasibility of transverse and longitudinal cooling with bunched beams. This plan should be submitted to DOE by December 31, 2007.

Scientific and Technical Staff

Findings:

In the last year, the RHIC Collaborations have published a large number of papers: STAR – 23, PHENIX -19. PHOBOS and BRAHMS, which continue to analyze their data, have published ~ 10 papers. The high impact of RHIC papers is reflected in a steady growth of citations, of about 1000 per year for each of the large Collaborations. RHIC has produced and continues to train young scientists, approximately ~ 25 Ph.D.s per year.

The publication record of the NT Group is as follows: in FY2006, 72 papers were published, of which 51 were in refereed journals. The scientific leadership of the theory staff is reflected in numerous prestigious awards, including, in 2007, the award of an APS fellowship and Humboldt Award.

The C-AD staff continues to maintain leadership positions in the community, including Chair of the Institute of Electrical and Electronic Engineers (IEEE) Particle Accelerator S&T, Chair of the U.S. Particle School of Governors and leadership of many prominent American Physical Society (APS) committees. Staff was honored with seven different awards in 2007, including BNL Science and Technology Award, Brookhaven Town Honor, American Association for the Advancement of Science (AAAS) Fellow and DOE Pollution Prevention Star Award. 2007 publications approach 100, of which 20 were refereed.

Comments:

The RHIC BNL experimental groups provide leadership, detector operations and computing support, and have research achievements with significant and noticeable contribution to the overall collaboration scientific productivity.

The number of important results obtained from the rather short pp runs and their timely presentation on conferences underlines the productivity of the RHIC experimenters.

The leading role of the theory effort is exhibited both through awards received by members during 2007, and by the continued production of highly cited papers.

BNL has demonstrated a world class core competence in beam polarimetry. The polarized proton jet polarimeter has attained a world record performance.

The C-AD staff has demonstrated a comprehensive command of the operational behavior of the RHIC beams as well as computational simulations of the beam dynamics. These efforts were critical to the ultimate success of the RHIC facility.

The C-AD provides leadership in the science of accelerators, is dedicated to the highest standards of performance, and the continuing inventions and development of new ideas for the future of RHIC. This excellence extends deeply into the organization, with a

number of staff members receiving recognition with awards in 2007. The productivity not only showed in the performance of the accelerator systems, but showed up in a number of publications, conferences and invited talks. Continued mentoring of students is part of the academic environment, and a cadre of ~25 Ph.D. students can claim the honor of being trained at Brookhaven in recent years.

Recommendations:

- None

Scientific Community

Findings:

The laboratory management interacts with the scientific community through the RHIC/AGS Program Advisory Committee (PAC) and the RHIC/ Alternating Gradient Synchrotron (AGS) User group organization in addition to interactions with the RHIC collaborations. The size of the RHIC User community is about 1100 individuals.

The RHIC Users' Group sponsors four meetings per year to discuss scientific and technical issues in the program. The major concerns of the User Community pertain to funding issues, visa issues, quality of life at BNL, and staying abreast of changing rules and regulations.

Comments:

The RHIC User group appeared well organized, active, well informed and seemed to work well with laboratory management.

BNL and RHIC management should continue to develop better communication mechanisms for interaction with the leadership of the RHIC collaborations, particularly when RHIC develops its strategic and operational plans.

Recommendations:

- None

Management

Findings:

Management has responded to the two action items from the 2006 S&T Review related to CE and AIP at RHIC and the plans for R&D required for the luminosity upgrade (RHIC II).

In February, 2006, BNL Management presented to DOE a RHIC Mid-Term Strategic Plan followed by a Mid-Term Strategic Plan Update and Status Report, presented to DOE in July, 2007. These plans address scientific goals, technical development of the accelerator facility and upgrades to the PHENIX and STAR detectors, together with the required R&D investments.

The RHIC Mid-Term Strategic Plan presented costs and schedule for the five years (2006-2011) based on an assumption of timely completion of all the instrumentation projects and a run schedule based on 30 cryo-weeks of RHIC operation per year.

Beyond the RHIC Mid-Term Strategic Plan (2006-2011) Laboratory management is developing the motivation and technical framework for the design and construction of a luminosity upgrade (RHIC II) and an electron-ion collider (eRHIC). Aspects of these plans have been presented to NSAC in the development of the NSAC Long Range Plan for U.S. Nuclear Physics.

A new BNL Associate Laboratory Director for Nuclear and Particle Physics (NPP) has been appointed effective September 2007. A new BNL Head of the RHIC/ATLAS computing facility has been appointed as of February, 2007.

The total DOE Nuclear Physics budget at BNL for FY 2007 was about $170 million (including "landlord" funding). The FY 2007 budget for the BNL LDRD program is about $13 million of which ~ $2 million was directed towards RHIC activities. The total discretionary funds expended by Laboratory management in FY 2007 in support of the NP program are approximately $6 million.

As presented, the core competencies at BNL related to the RHIC program are the:

- design, construct and operate extraordinary facilities;
- development of advanced concepts of accelerators, detectors, magnets, and instrumentation; and
- development of tera (peta)-scale computing.

The RHIC program is addressing 12 DOE NP performance measures as defined by NSAC.

The RHIC facility presents a complex work environment and represents an essential and challenging component of the BNL safety management program.

The Instrumentation Division continues to respond to the technological needs of the RHIC program, for example in the development of application specific integrated circuits.

Funding short falls in the RHIC program were identified in the areas of R&D funding, capital equipment, and experimental support, both in 2007 and in the projections into the out years. Approximately $3-5 million a year is needed for investments in fire safety upgrades and electrical infrastructure ($1-2 million/year) which could have a significant impact on operations if funds have to be identified from accelerator operations.

Comments:

Laboratory management is appropriately maintaining and developing core competencies in the design and construction of innovative accelerator systems, magnets, detectors, and computing, in support of the RHIC nuclear physics program.

The safety record of the C-AD and RHIC has continued to improve which is indicative of a staff and management which are committed to and effective in developing a safe work environment.

In the context of the migration of collaboration research staff to the LHC, the availability of the workforce needed to carry out the research program, complete R&D, and construct the RHIC detector upgrades seems to be manageable.

The staffing and funding of the new BNL HIR group, focused on the LHC ATLAS detector, should be evaluated from the perspective of critical mass and scientific impact as it develops in the coming years. Some reviewers believe that ultimately engaging in ATLAS is a question of BNL's priorities – how high is the priority, at what expense to RHIC, and is the laboratory willing to commit long-term resources?

Although the Mid-Term Strategic Plan identifies the facility goals leading up to the proposed luminosity upgrade, the scientific goals of RHIC II as well as the longer term scientific goals and case for eRHIC will continue to need formulation and development especially in the context of the new NSAC Long Range Plan. The eRHIC facility is considered by BNL to be a central part of the long term future of the laboratory, but it is only one of several options to realize an Electron-Ion Collider (EIC).

The Mid-term strategic plan should continue to be periodically updated with broad theoretical input, especially from the laboratory. Some reviewers thought the scientific implications of the LHC heavy-ion program at CERN should to be folded in.

Laboratory management is making significant progress in addressing the NSAC/DOE performance measures for the RHIC facility. Currently all measures are on track for completion by the identified target dates.

The local BNL groups and the Collaborations are encouraged to continue to work together to define an appropriate distribution of responsibility in detector maintenance and operation support.

Laboratory Management needs to continue its review and prioritization of funding for the experimental program and accelerator operations with respect to the distribution of R&D funding, experimental support, development of upgrades, capital equipment, in the context of projected shortfalls in the out years, ongoing efforts by the collaborations to identify additional workforce, and infrastructure needs.

Recommendations:

- None

Appendix A: Action Items from 2006 Science and Technology Review

- Generate a risk assessment of the backlog of Capital Equipment (CE) and Accelerator Improvement Projects (AIP) requests and submit to DOE by January 25, 2007.

  Status: A risk assessment report of CE and AIP was submitted on January 31, 2007 to DOE NP.

- A Research and Development (R&D) plan for increasing machine luminosity should be generated which defines milestones, performance goals and deliverables, required resources, critical path and schedule contingency, in the context of what is needed for implementing the Mid-Term Strategic Plan and the proposed RHIC II. The plan should include 'checkpoints' that allow a re-evaluation of the design proposal at the critical planning points. This plan should be delivered to DOE by January 31, 2007.

  Status: A Research and Development (R&D) plan was submitted on January 22, 2007 to DOE NP.

Appendix B: Charge Memorandum

Thank you for agreeing to participate as a panel member for the annual Science and Technology (S&T) Review of the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL). Thank you for agreeing to participate as a panel member for this review that will take place at BNL on July 18-20, 2007.

The RHIC facility plays an essential role in two major scientific thrusts of the U.S nuclear physics program, the national heavy-ion program and spin physics program. As the primary sponsor of U.S. nuclear physics research and the operations of RHIC, it is important for the Office of Nuclear Physics to understand the progress and future potential of these two research programs, the effectiveness of RHIC operations and whether resources and planning are being directed optimally to achieve the scientific goals of the Nation's nuclear physics program.

In carrying out this charge, each panel member is asked to evaluate and comment on:

- The quality, productivity, and significance of the laboratory's scientific and technical accomplishments and the merit, feasibility and impact of its future planned physics program;

- The effectiveness and appropriateness of facility operations and the planning for future facility upgrades in support of the research program;

- The effectiveness of management in strategic planning, developing appropriate core competencies, implementing a prioritized and optimized program, and promoting and implementing a safe work environment;

- The leadership, creativity, and productivity of the facility's scientific and technical staff in carrying out the above activities; and

- The quality and appropriateness of the laboratory's interactions with, and nurturing of, its scientific community.

The review should comment on what progress has been made towards addressing action items from the previous Science and Technology Review.

The first two days will consist of presentations by the laboratory, and executive sessions. The third morning will be used for an executive session and preliminary report writing; a brief close-out will take place in the early afternoon. Preliminary findings, comments and recommendations will be presented at the close-out.

You will be asked to write individual "letter reports" on your findings. Your "letter report" will be held in strictest confidence, so please be candid in your written remarks. The review will be chaired by Dr. Gulshan Rai, Program Manager for Heavy Ion Nuclear Physics, Office of Nuclear Physics. We will accumulate your "letter reports"

and compose a summary report based on the information in the letters. The "letter reports" will be due at DOE two weeks after the conclusion of the review.

An agenda and background material, as well as travel and housing information, will be sent to you directly from BNL. The laboratory will make word processing and secretarial assistance available during the review. If you have any questions about the review please contact me at (301) 903-1455, or Email: Jehanne.Simon-Gillo@science.doe.gov or Dr. Gulshan Rai at (301) 903-4702, or E-mail: Gulshan.Rai@science.doe.gov. For logistics questions, contact Elaine Zukowski at RHIC at (631)-344-3830 or E-mail: zukowski@bnl.gov.

I greatly appreciate your willingness to assist us in this review. This is a very important process, and it helps to insure the highest quality scientific program at BNL. I look forward to a very informative and stimulating visit.

Sincerely,

Jehanne Simon-Gillo
Director
Facilities and Project Management Division
Office of Nuclear Physics

Enclosure

Appendix C: Agenda and List of Reviewers

Annual DOE/Nuclear Physics Review
of RHIC Science and Technology

July 18-20, 2007
Berkner Hall, BNL

Agenda

July 18, 2007

Berkner Room B

0745	Panel members arrive, set-up laptop and seated	
0800	DOE Executive Session	
0845	Welcome	S. Aronson
0900	**Overview Associate Director's Perspective**	P. Bond

- Vision, Priorities & Prospects – Mid-term and Long term
- Core Competencies
- Overview of RHIC operations
- Response to previous DOE S&T review
- Reorganization and Lab support of NP

0930	**PHENIX** RHIC Accomplishments, Status, Plans & Issues	B. Jacak
1010	Break	
1030	**STAR** RHIC Accomplishments, Status, Plans & Issues	T. Hallman
1110	**CA-D Operations overview**	D. Lowenstein

- Status and Facility Performance of RHIC
- RHIC Machine Performance, Technical Accomplishments
- Projections
- Plans – How are they integrated with the BNL Strategic plan,
- Issues

1155	**SPIN** RHIC Accomplishments, Status, Plans & Issues	L. Bland
1230	LUNCH and DOE Executive Session	
1400	**Update of the Mid-Term Strategic Plan**	T. Ludlam

1500 **RHIC Operations and Evolution** T. Roser

- Prospects and plans to increase luminosity and polarization
- Impacts on plans on the scientific research
- Issues

1545 DOE Executive Session

18:00 Questions for BNL – Homework

July 19, 2007

Berkner Room A

0800 DOE Executive Session

- 8:20 am (15 minutes with STAR spokesperson)
- 8:35 am (15 minutes with PHENIX Spokesperson)

<u>Breakout Session A</u>: Accelerator Operations and Infrastructure Berkner Room C

0900 **Accelerator Performance Analysis** A. Drees
0940 **Polarization & Luminosity Improvement** M. Bai

1010 **RHIC Stochastic Cooling** M. Brennan

- Status of R&D – Upgrades, competencies needed
- Prospects and plans to establish feasibility
- How is the accelerator R&D integrated with BNL Strategic Plan? Impacts?
- Issues

10:40 Coffee Break

1100 **RHIC R&D – ERL and eCooling** I. Ben-Zvi

- Status of R&D – Upgrades, competencies needed
- Update on plans to establish feasibility
- How is the plan integrated with BNL Strategic Plan? Impacts?
- Issues

1130 **Accelerator Development for eRHIC** V. Litvinenko
1150 **AIP and CE Plans for RHIC** W. Fischer

1230 Lunch and DOE Executive Session

1400 Plenary Session in Room B

<u>Breakout Session B</u>: Scientific Program **Berkner Room B**

0900	**Nuclear Theory Program and RBRC** ▪ Interplay between theory and experiment program	D. Kharzeev
0940	**The Lattice Gauge Theory Group**	F. Karsch
1000	Coffee Break	
1010	**BNL Experimental Scientific Groups** ▪ Research and experiment operations: productivity, accomplishments, and issues	
	PHENIX	D. Morrison
	STAR	TBD
	New Heavy Ion Research Group	F. Videbaek
11:25	**RCF Operations and plans** ▪ Status and Facility Performance of RCF ▪ Plans & Needs in the context of BNL Strategic Plan ▪ Accomplishments and productivity technical staff ▪ Present resource allocation, including manpower and equipment ▪ High-level breakout of funding of RCF activities and capital equipment turnover. ▪ STAR and PHENIX Computing Issues	M. Ernst
1200	**Discussion**	
1230	Lunch and DOE Executive Session	
1400	Plenary Session in Room B	

Plenary Session Berkner Room B

1400	**Polarimetry Physics/CA-D program and coordination**	G. Bunce
1420	**Instrumentation**	G. DeGeronimo
1440	**Safety**	E. Lessard
1500	**RHIC Users presentation**	J. Hill

1520	Coffee Break
1530	**BNL Response to Questions**
1600	DOE Executive Session
1800	Questions for BNL

July 20, 2007

Berkner Room B

0800	**Questions and Answers with Laboratory Management**
0900	DOE Executive Session and Report writing
1400	Review Close Out
1430	Adjourn

Relativistic Heavy Ion Collider Science & Technology Review
July 18-20, 2007

Review Panel

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