BNL Strategic Plan for Nuclear Physics
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Abstract: The strategic plan for Nuclear Physics at Brookhaven National Laboratory seeks to align itself with the strategic goals of the U.S. Department of Energy[1] and to maximize the scientific contributions of the Laboratory to the advance of nuclear physics. To accomplish these guiding principles, we seek to identify strategic research directions where BNL offers unique scientific and technical expertise, together with existing and newly constructed accelerator facilities, to pursue innovative and productive paths for advancing nuclear physics. We capture our plan in abbreviated form in a simple matrix that is explained, project-by-project, in the sections below. In the matrix, the *data taking periods* are shown vs. time without their relevant construction periods. The data taking periods, of course, are when these experiments begin contributing to the advance of nuclear physics. We also note the impact of theory, accelerator physics and superconducting magnet R&D activities on our nuclear physics program in the main text.

Time Interval	FY05-06	FY07-08	FY09-10	FY11-12	FY13-14	FY15-16	FY17-18
Quantum Chromo-Dynamics (QCD) & Nucleon Structure	RHIC RHIC-Spin LEGS	RHIC RHIC-Spin	RHIC RHIC-Spin	RHIC II RHIC-Spin	RHIC II RHIC-Spin	RHIC II eRHIC	RHIC II eRHIC
Neutrino Physics	SNO	SNOLAB	Δs ν Exp.	Reactor ν Exp.	Reactor ν Exp.		
Theory	Analytic Lattice	Analytic Lattice	Analytic Lattice	Analytic Lattice	Analytic Lattice	Analytic Lattice	Analytic Lattice

Executive Summary of the Plan

The strategic plan for Nuclear Physics at BNL continues the historical mission of the U.S. Department of Energy (DOE) National Laboratories as sites for accelerator based user facilities for experimental programs that are not practical for construction and operation in university venues. These large national facilities are intended for use by qualified researchers from all interested universities plus other research institutions in the U.S. and abroad to advance the field of nuclear physics. In pursuing this plan, we assume that the national program will be guided by a principle of maximizing important nuclear physics advances relative to invested resources and that the current tight funding circumstances will not soon improve. Because the RHIC and AGS-based portions of this plan require the investment of significant new resources by the DOE, as well as by collaborating institutions abroad, we assume that nuclear physics resources will be allocated nationally on a model of maximizing science value and that BNL initiatives will compete for new resources with other important U.S. nuclear physics programs. This competitive resource allocation principle has been promulgated to the national program by administration policy makers. We note that RHIC II and eRHIC are among the important policy priorities for future U.S. Nuclear Physics programs that have been provided by the U.S. Government[1,2] and by the DOE's Nuclear Science Advisory Committee (NSAC)[3]. BNL's plan aligns well with this guidance.

We also note the particular value and applicability to our plan of the installed accelerator capability at BNL, especially the Relativistic Heavy Ion Collider (RHIC) and its injector complex machines,

[1] "Facilities for the Future of Science", http://www.science.doe.gov/Sub/Facilities_for_future/facilities_future.htm
[2] "Physics of the Universe", OSTP, February 2004, http://www.ostp.gov/html/physicsoftheuniverse2.pdf
[3] NSAC Long Range Plan, http://www.science.doe.gov/henp/np/nsac/nsac.html

the Alternating Gradient Synchrotron (AGS), the Booster, Linac and others. RHIC is currently operating as the world's premier facility for the exploration and characterization of states of nuclear matter produced at very high energy density and temperature, a study that has been characterized as the search for and exploration of 'Quark Gluon Plasma' (QGP), a generally accepted identifier for the de-confined state of nuclear matter under these extreme physical conditions. The RHIC facility also features high-energy, polarized-proton colliding beams for understanding the spin structure of the proton, a second very important and unique basic research capability. For the next few years, the existing RHIC facility will take data intensively to characterize more fully, the exciting discoveries already seen in heavy ion collisions and will progress effectively in the program of proton spin investigations using the RHIC polarized proton beams. In parallel, the RHIC machine and its two large detectors, PHENIX and STAR, will benefit from modest capital upgrades to improve their technical capability to pursue the research program prior to the more extensive upgrades planned for the RHIC II and eRHIC Projects planned to follow in later years.

The flexibility and rather low duty-cycle use of the AGS injector complex for RHIC also provides a very economical basis for employing the AGS and Booster accelerators as important experimental venues for other scientific uses, among them the NASA Radiobiology Program that has been employing Booster and AGS ion and proton beams for several years and the upcoming NSF 'Rare Symmetry Violating Processes' (RSVP) experiments, KOPIO and MECO, that will use the AGS in future years. In January 2004, a special review panel of the DOE examined the feasibility and impact on the RHIC program of using the AGS complex for other scientific missions in a parasitic mode and concluded that there were no significant negative impacts on RHIC. In fact, the panel concluded that more intensive use of the AGS would, in fact, improve its operational reliability, hence providing a net positive benefit to the RHIC program. This is a key result for the practicality of our ongoing RHIC facility use and strategic Nuclear Physics plan.

As a theoretical physics complement to these present and future uses of the RHIC accelerator and experiments complex to test predictions of Quantum Chromodynamics (QCD) theory, the future of *lattice gauge supercomputing* at BNL has improved significantly in recent times. In addition to recruiting a very strong new lattice gauge physicist, Frithjof Karsch, to head the nuclear physics lattice gauge theory effort, BNL has also advanced its capability to provide on-site supercomputing dedicated to lattice gauge physics. Funding was provided by DOE for a 10 Tflops peak, 'QCD-On-a-Chip' (QCDOC) supercomputer at BNL, that will provide important supercomputing capability for the national lattice gauge theory community by spring 2005. This machine will be combined with an identical QCDOC machine operated by the Riken BNL Research Center at BNL to provide the community with a particularly strong computing capability (20 Tflops peak) dedicated to advancing the growing and important field of lattice gauge physics. Applications in nuclear physics, especially QCD theory predictions, will be a large part of the lattice gauge physics computations carried out on the twin QCDOC supercomputers at BNL.

Two very important future projects, RHIC II and eRHIC, were listed in the DOE Office of Science 'Facilities for the Future of Science' plan[1]. These new facilities are important for the scientific evolution of the DOE's future program in heavy ion nuclear and nucleon spin physics. The physics thrust of RHIC II was noted favorably in the U.S. Government's 'Physics of the Universe' policy document[2] issued by the Office of Science and Technology Policy in 2004. Both new facilities will also extend the study of proton spin into important new topical areas. BNL anticipates that these two projects will move ahead to the status of approved and funded construction projects. RHIC II embodies collider luminosity and detector capability upgrades that will open up important new topics in RHIC physics for investigation around 2011. Questions that can only be answered with very large integrated heavy ion data sets or that require significant new detector capabilities will allow the exploration of topics in QCD that cannot be engaged in any other way. The eRHIC Project will add a 5-10 GeV, variable-energy, polarized-*electron* beam, to collide with existing RHIC heavy *ion* and polarized *proton* beams, as well as a new experimental detector to study these collisions. eRHIC will probe nuclear and nucleon spin structure with electromagnetic and weak boson probes in the highly relativistic regime for the first time ever. This regime makes accessible to detailed measurement, new phenomena, such as the 'Color Glass Condensate' (CGC), that await investigation and full characterization with the unique research capability of eRHIC's high energy electron-ion collider.

The BNL Nuclear Physics program features several additional important investigations and future initiatives in addition to the RHIC physics flagship program. One is the ongoing LEGS experiment at BNL's National Synchrotron Light Source (NSLS), in which the electromagnetic properties of polarized proton and neutron targets are probed with a backscattered polarized laser photon beam. LEGS is expected to take data through FY 2006. A second important area of investigation has been in the field of neutrino physics. BNL has been an important collaborator in the Sudbury Neutrino Observatory (SNO) experiment that, along with other beautiful neutrino experiments, confirmed the existence of neutrino mass and observed the phenomenon of neutrino oscillations. The SNO work continues a BNL tradition that began with the solar neutrino experiment of BNL Nobelist, Ray Davis, and continued with other AGS-based neutrino experiments in the 1970s and 1980s. BNL's SNO collaborators are based in the Chemistry Department from which they brought specialized expertise to SNO and are now planning to bring this expertise to a newly proposed reactor neutrino experiment that seeks to measure (or set tighter upper bounds on) the key neutrino oscillation parameter, $\sin^2(2\theta_{13})$.

We also note the strong positive reception given by the BNL Program Advisory Committee[4] to a recent 'Letter of Intent' (LoI) submitted to BNL by a newly-formed, multi-university collaboration of younger nuclear physicists, who seek to measure the strange quark contribution to the nucleon spin by comparing neutral current with charged current neutrino scattering in a low energy experiment at the AGS, the 'Δs Neutrino Experiment'. We expect the LoI to develop into a strong and compelling proposal in the near future.

BNL also supports ongoing theoretical physics, advanced accelerator and superconducting magnet R&D programs, and a National Nuclear Data Center that are all related to the advance of the national nuclear physics agenda. These programs are commented on in the main text. To put the new BNL initiatives in a realistic operational time context, we also include an R&D/Construction matrix as a separate section of the text below.

[4] BNL HENP Program Advisory Committee Recommendations, http://www.bnl.gov/henp , follow links to PAC

Contributions of the Strategic Plan Experiments to the Advance of Physics

Each of the physics projects in the abstract matrix is briefly discussed in the paragraphs below, noting both their contributions to world physics and their approval or operational status in the national forum. The experiments are discussed in rough time order of data taking, starting with experiments that are currently actively taking data. The preparation periods are of significantly varying duration among the new or future projects and these periods do not contribute directly to the advance of the relevant science areas. Therefore, we take the *availability of new scientific results from the experiments* as the appropriate measure of their scientific impact. In the last section of this plan, we address the related construction activities in a second matrix to provide a more complete picture of Laboratory activity.

<u>RHIC Experiments[5]:</u> The RHIC experiments to date have been performed in four experimental detectors, BRAHMS, PHENIX, PHOBOS and STAR, at four interaction points around the RHIC rings. The RHIC collider has accelerated, stored and collided beams of heavy ions and polarized protons. The heavy ion physics program is fully integrated with the polarized-proton spin physics program and both physics programs take data in the same set of experimental detectors. We briefly discuss these two co-evolving physics programs here:

Heavy Ion Physics – Since 1999, the RHIC heavy ion physics program has exceeded expectations both for collider performance and for the quality and speed of presentation of discovery scientific results by the four RHIC Collaborations, BRAHMS, PHENIX, PHOBOS and STAR. In that time, basic measurements of Au-Au collisions at four beam energies, p-p comparison data at one energy and d-Au at one energy have been made and the first physics results published. These results have confirmed the existence of a produced state of nuclear matter in Au-Au collisions with exceedingly high energy density that is thermalized in a fraction of a Fermi and that subsequently evolves as a strongly-interacting, ideal nuclear fluid, finally freezing out into thousands of mesons and hundreds of nucleons. Such a state has never before been seen under experimental conditions. This fluid appears to be a *strongly-interacting form of 'quark gluon plasma'* earlier predicted by theorists, but generally expected to be weakly-interacting. Thus, the experimental result was both a surprise and a confirmation. For the next few years, the RHIC experiments will run to further explore properties of this 'sQGP' plus many other novel and interesting physics questions. During this time, the PHENIX and STAR experiments will be significantly upgraded to be able to expand their range of measurements plus improvements will also be made to the RHIC machine complex. In this period, many of the basic questions accessible to RHIC will be addressed and answered. Remaining to be investigated are additional topics that are of high physics interest, but that require the enhanced luminosities and more fully upgraded detectors to be provided in the RHIC II Project discussed below.

Spin Physics - The RHIC spin (RHIC-Spin) program investigates the spin structure of the proton by colliding beams of *polarized* protons at high energy and luminosity. The protons in one colliding beam are probed by the polarized quarks and gluons of the other colliding beam. The RHIC spin program is able to precisely measure the proton spin contribution from gluons and separate out the spin contributions from quarks and anti-quarks, identified by quark flavor. The proton-proton collisions also provide important baseline collision data for the heavy ion program. The spin

[5] RHIC Experiments website, http://www.bnl.gov/cad ; http://www.phy.bnl.gov/ ; http://www.phobos.bnl.gov ; continue with links to the RHIC Experiments

program plans to measure the gluon polarization precisely for collisions at $\sqrt{s} = 200$ GeV, followed by measurements of the anti-quark polarizations in parity-violating W boson production at $\sqrt{s} = 500$ GeV. To accomplish this, RHIC proton beam polarizations of 70% (up from 45%) will become available in the near future and proton beam luminosities will be increased by up to a factor of 15 over the next few years. Upgrades of the present experiments will be necessary to reach the W physics goals. These upgrades include improved online data selection, a micro-vertex detector and a nose cone calorimeter for PHENIX, plus special tracking and a forward electromagnetic calorimeter for STAR. Other detector improvements are also being studied.

LEGS[6]: The Laser-Electron-Gamma-Source (LEGS) currently provides intense beams of monochromatic and polarized Gamma rays (photons) with energies up to 420 MeV on polarized, solid hydrogen-deuteride (HD) targets developed and built at BNL. These novel targets provide unique experimental capability for studying neutron properties. The physics program is focused on the proton and neutron *spin-polarizabilities*, the strengths of the transient dipole moments which tend to orient the nucleon spin along the photon beam during scattering, and on *spin-sum-rules* (SR), such as the Gerasimov-Drell-Hearn SR that tests the $Q^2 = 0$ limit of the Bjorken SR. These sum rules are energy weighted and make their greatest contributions at LEGS energies. A broader goal of the program is the determination of the nucleon π-photoproduction amplitude (particularly for the neutron) a parameter that is poorly determined from the very limited body of existing data. Combining better neutron measurements with existing proton data will determine the isospin=1/2 amplitude for photo-pion production. Accurate knowledge of this amplitude will test models of nucleon structure in regions not accessible to Chiral Perturbation Theory. Completing the full, contemplated nuclear physics program is expected to require data taking through FY 2006.

SNO[7]: This experiment has made a set of beautiful measurements of the properties and fluxes of solar neutrinos as they arrive at the SNO detector, deep underground in the Sudbury nickel mine in Sudbury, Canada. By making the first direct measurement of the neutral-current (NC) flux of solar neutrinos (from the ^{8}B branch) at the same time that it measured the charged-current (CC) and elastic-scattering (ES) fluxes, SNO solved the long-standing Solar Neutrino Problem that had been discovered by Nobelist Ray Davis of BNL. SNO has now demonstrated (independent of solar models) that: only one-third of electron-flavor solar neutrinos reach Earth as electron-flavor neutrinos; two-thirds of the solar neutrinos oscillate into mu- and tau-flavor neutrinos; the total measured ^{8}B solar neutrino flux, summed over all flavors, is equal to the flux predicted by the Standard Solar Model. In 2004, SNO entered its third phase of operations, wherein the neutrons that are the signal of the NC interaction, will be measured by a new method, event-by-event, using ^{3}He-filled proportional counters ("Neutral Current Detectors," NCDs) that have been inserted into the 1-kiloton of D_2O. At the same time, SNO will be able to make an improved, cleaner measurement of the CC and ES fluxes. The SNO Collaboration, including BNL, is now discussing several options for possible future experiments that could be done in the SNO vessel after 2006 in the newly designated SNOLAB that has been funded by the Canadian Government and that is currently under construction in Sudbury. None of these options has been selected yet by the SNO collaboration as the best candidate to uncover new physics.

Δs Neutrino Experiment[8]: The strange quark (s-quark) contribution to the spin structure of the nucleons is still uncertain a quarter century after Nobel Prize winning experiments showed that

[6] LEGS Experiment website, http://www.LEGS.bnl.gov/
[7] SNO Exp. website, http://www.bnl.gov/chemistry/programs/neutrino.asp ; http://www.sno.phy.queensu.ca/
[8] http://www.bnl.gov/henp/ , follow links for Program Advisory Committee recommendations

nucleons are made-up of quarks and gluons. It is now clear that low energy neutrino experiments are the best way to resolve this uncertainty and address other interesting and important physics questions about nucleon properties. This subject was addressed and a favorable recommendation made in the recent APS Neutrino Study[9] sponsored by DOE, NSF and NASA. Now, a new 'Letter of Intent' (LoI) has been submitted to BNL by a newly-formed, multi-university collaboration of younger nuclear physicists, who seek to measure and compare neutral current (isoscalar + isovector) with charged current (pure isovector) neutrino scattering in a low energy experiment at the AGS, the 'Δs Neutrino Experiment'. The goal of this new experiment is to determine, unambiguously, the contribution of the s-quark to the spin of the nucleon and measure other low energy properties of the nucleons, all in the same experiment. The Δs determination is a very important step in the advance of the nucleon structure field and this topical focus currently comprises an important segment of the experimental program at the Jefferson Laboratory. The Δs neutrino experiment is the most direct and theoretically sound method for determining the contribution of the strange quark to the spin of the nucleon and would provide results not obtainable in electron scattering experiments. The Δs experiment will complement the RHIC proton spin measurements already underway. Because of our history in performing low energy neutrino experiments in the past, BNL's AGS machine is uniquely positioned to carry out the Δs experiment rapidly and economically. The new experimental detector is rather small for a neutrino experiment and could also be constructed economically in a couple of years with adequate capital funding.

Reactor Neutrino Experiment[10]: The subject of neutrino oscillations has captured the scientific interest of large numbers of experimental and theoretical nuclear and particle physicists in the last decade. One of the most striking aspects of our evolving understanding of the oscillations is the fact that, while two of the neutrino mixing angles, θ_{12} and θ_{23}, have been measured and are large (~32° and 45°, respectively), θ_{13} is known to be small, with only an upper limit (<11°) established, so far, using data from nuclear-reactor based experiments. Now, new experiments have been proposed to measure θ_{13} with high precision, down to values of $\sin^2(2\theta_{13}) \sim 0.01$, corresponding to $\theta_{13} \sim 3°$. The new proposals are all reactor-based disappearance experiments that will search for deviations from the $1/r^2$ dependence of the antineutrino fluxes and for distortions in the energy spectra as evidence of oscillations. These experiments will use two or more identical antineutrino detectors placed underground at distances from the reactor r ~ 100 m and ~ 2000 m. At the short distance, no oscillations are expected to occur, while at the longer distance, oscillations should be observed. The key to achieving the required high precision is the fact that comparison of the signals from these identical detectors will eliminate most of the systematic errors. It is planned to cross-calibrate the detectors by moving them so as to replace a near detector with a far one and vice versa. The new proposals have received a very positive, high priority recommendation in the recent APS National Neutrino Study[9] and we anticipate that at least one of them will be approved and built. BNL research chemist, Richard Hahn, has been recruited to join all of the proposing groups because he and his group bring unique expertise to these experiments' advanced needs for gadolinium-loaded liquid scintillators (Gd-LS) to serve as the antineutrino detection medium, a critical aspect of all the reactor proposals submitted to dates. The BNL group will also study the chemical compatibility of the Gd-LS with the construction materials of the detector vessel, such as acrylic, and will apply its experience in solar neutrino R&D to the determination and control of radioactive and chemical contaminants in the antineutrino detector.

[9] APS Neutrino Study website, http://www.interactions.org/cms/?pid=1009695
[10] Reactor Neutrino website, http://www.bnl.gov/chemistry/programs/neutrino.asp ; http://theta13.lbl.gov/ ; http://braidwood.uchicago.edu/

RHIC II[11]: The early discoveries of the RHIC heavy ion (HI) program have opened the way for a new field of research exploring the fundamental properties of the strong interaction in high-energy-density states of matter described by QCD. These extreme states provide a unique laboratory for the study of extended systems whose properties are governed by the strong (color) force. As the RHIC program moves beyond the initial, "discovery" phase it will be in a position to address very basic questions regarding the properties and origins of this form of matter, the strongly coupled quark gluon plasma (sQGP). Two of the 'Big Questions' we will ask are: What physics governs the interaction of strong color fields? What are the physics manifestations of super-dense, strongly interacting matter? These Big Questions generate a number of more-specific, answerable questions for experiment and theory that will be addressed in the RHIC II program. Examples: What is the nature of the phase transition between quark matter and nuclear matter? How are hadrons formed? What are the properties of strongly coupled quark gluon plasma? What are the transport properties, collision probabilities, screening length, etc. of sQGP? Is chiral symmetry restored and what are its observable effects? Is the initial state in HI collisions a Color Glass Condensate? The needed measurements will require large data samples, taken over long running periods, with varied HI beam conditions. The RHIC II facility is well matched to the pursuit of these physics questions. We note that the Large Hadron Collider at CERN will begin a survey of HI collisions later in this decade at collision energies about 30 times greater than RHIC. The LHC program will add a new exploratory phase to HI research. The states produced at LHC may be quite different from those produced at RHIC, and will address physics questions complementary to the RHIC II program. To accomplish the RHIC II physics goals, BNL proposes to increase the collider luminosity by an order of magnitude for heavy ion collisions and upgrade the PHENIX and STAR detectors to provide high-rate sensitivity to the radiation of quarks, photons, and leptons created during the earliest stages of the collisions. The electron-cooled ion beams needed and provided by RHIC II will constitute a first key step toward the realization of eRHIC as discussed in the next section.

eRHIC[12]: In the next development phase of the RHIC complex, a new *electron* storage ring will be added to provide the unique capability of colliding *polarized electron beams* in the range, 5-10 GeV, with the heavy ion and polarized proton beams in RHIC. The eRHIC physics will require building a new detector to study e-A/p collisions at the new electron-ion interaction point. The addition of this high-intensity, high-energy polarized electron/positron beam facility in the RHIC complex, to collide with the already existing heavy ions beams of the RHIC, will significantly enhance RHIC's capability to explore fundamental and universal aspects of QCD. Collisions with the polarized proton beam will enable precision studies of nucleon spin. The facility will be unique and will attract nuclear and particle physics communities from around the world to pursue experimental studies of QCD in the next decade. Examples of nuclear physics areas that will be productively expanded by eRHIC include: the *structure* of hadrons in terms of their quark and gluon constituents; the *evolution* of quarks and gluons into hadrons; the quark/gluon *connections* to properties of atomic nuclei? There are also completely new questions that are the special province of eRHIC. Does partonic matter saturate in a universal high-density state (Color Glass Condensate)? Are there long-range correlations among produced partons? Can studies of the dependence of the parton densities on the nuclear density help constrain the properties of nuclear matter in the center of a neutron star? To what degree can QCD be demonstrated as an exact theory of the strong interaction? Answers to these questions in the form of direct comparisons with QCD theory will require eRHIC experimental data interpreted with the results of advanced lattice gauge physics calculations that will become available in the same time frame. For example, collisions

[11] RHIC II website, http://www.bnl.gov/rhic , follow RHIC II links
[12] eRHIC website, http://www.bnl.gov/eic/

with polarized protons will yield precision studies of nucleon spin properties to compare with precision QCD predictions. The eRHIC facility will be unique and will attract nuclear and particle physics communities from around the world to pursue experimental studies of QCD.

Theoretical Physics[13]: The Nuclear Theory Group at BNL is one of the strongest in the country and has focused on the connections between theory and experiment, especially the exciting RHIC experiments that are of particular interest to the experimental NP community at BNL and to the worldwide RHIC users. The nuclear theory group has grown vigorously during the past few years. The BNL nuclear theorists, working side by side with nuclear theorists in the Riken BNL Research Center, interact closely and productively with RHIC experimental physicists. They play a clear and important leadership role by helping the BNL RHIC community towards important and productive new physics directions. In addition to an historically strong focus on analytical methods and phenomenology goals, the nuclear theory group is now rapidly growing and is contributing to the maturing and increasingly important field of lattice gauge physics as well. A new lattice gauge theory leader, Frithjof Karsch, has recently joined BNL; interactions between his new group and the existing nuclear theory group will further strengthen the overall theoretical nuclear physics program at BNL. On the lattice gauge side, we are matching the physicist effort with state of the art superconducting computing capability, QCDOC supercomputers now being installed at BNL, that will support these efforts with world-competitive supercomputing resources. Maintaining the strength and effectiveness of the nuclear theory program, and its focus on the most important areas of nuclear physics for the continued advance of the BNL RHIC physics, will continue to be a primary goal of BNL.

Superconducting Magnet R&D[14]: The Superconducting Magnet Division (SMD) at BNL pursues the dual mission of developing novel and useful new superconducting (SC) magnet designs and materials as well as building small numbers of superconducting magnets that are not cost-effective for industry to produce or for other laboratories around the world to design and build themselves. For the RHIC program, the focus in recent years has been on superconducting ‘snake’ magnets for the RHIC ring and the AGS to preserve RHIC full-energy proton beam polarization up to 70% for the RHIC Spin program and for superconducting ‘spin rotator’ magnets that allow the PHENIX and STAR experiments to independently select arbitrary proton spin polarization directions at their collision point during spin data runs. The Division must also be ready to build and supply spare superconducting RHIC magnets to replace damaged magnets in the RHIC rings. So far, there has been failure only in one of the spin rotators but other magnet failures are always possible. Tooling has been preserved from the RHIC magnet construction era to maintain this vital repair capability. Future Nuclear Physics missions could include design and production of superconducting magnets for the RIA facility now under consideration by the DOE ONP.

National Nuclear Data Center[15]: This Center provides the national nuclear physics and nuclear technology communities with a well maintained, critically reviewed and accurate source of archived nuclear data in easily accessed databases. The National Nuclear Data Center (NNDC) is the United States repository for nuclear physics data maintained in an archival format. The data are gathered through the efforts of the NNDC and its national and international collaborators. The NNDC is responsible for data compilation, evaluation and information services for neutron, charged particle, and photonuclear reactions, radioactivity, and nuclear structure physics. The NNDC maintains

[13] BNL HEP Theory website, http://thy.phy.bnl.gov/
[14] BNL Superconducting Magnet website, http://www.bnl.gov/magnets
[15] BNL National Nuclear Data Center website, http://www.nndc.bnl.gov/

databases with bibliographic, experimental, and evaluated data for these areas of nuclear physics, distributes databases to its national and international partners and provides data services to basic and applied scientists in the United States and Canada. Maintaining a strong role in nuclear structure and reaction evaluations, compilation, archival of databases and dissemination, along with active response to user needs continues to be primary goal of the NNDC. The NNDC function is expected to go forward into the future as an ongoing service to the worldwide Nuclear Physics community.

R&D and Construction Projects Matrix

To indicate a time context for carrying out the construction phase of projects shown in the physics impact matrix of the Abstract for this plan, we show a second matrix here that provides BNL projected R&D and Construction Project (C) time frames that lead to the Operations (Ops) periods shown in the physics impact matrix. The periods shown as operations include commissioning time in cases where this is needed. BNL based experiments with no construction required are also shown here for completeness.

Project	FY05	FY06	FY07	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18
LEGS	Ops	Ops												
RHIC	Ops	Ops	Ops	Ops	Ops	Ops								
RHIC II	R&D	R&D	R&D	R&D	C	C	C/Ops	C/Ops	C/Ops	C/Ops	Ops	Ops	Ops	
eRHIC	R&D	R&D	R&D	R&D	R&D	R&D	R&D	C	C	C	C	Ops	Ops	Ops
Δs ν Exp.	R&D	R&D	C	C	Ops	Ops								
Reactor ν	R&D	R&D	C	C	C	Ops	Ops	Ops	Ops	Ops				