DOE Review of the Impacts on RHIC of Continuation of E949 at the AGS

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Appendices

1. Introduction

E949 is a compelling experiment that was approved, constructed and began operations in U.S. fiscal year 2002 (FY02) under sponsorship of the U.S. Department of Energy's (DOE) Division of High Energy Physics (DHEP) at the Alternating Gradient Synchrotron (AGS) at Brookhaven National Laboratory (BNL). The experiment was not completed because DOE-DHEP terminated funds for the operation of the AGS in the President's FY03 budget. The completion of E949 was submitted as a new proposal to the National Science Foundation (NSF) and is under consideration for operations support at the AGS by that agency. Because this additional potential use is comparable to the Rare Symmetry Violating Processes (RSVP) experiments in its potential impacts on the RHIC program, DOE's Office of Nuclear Physics (ONP) asked that it be included in the review assessment.

The AGS accelerator complex is now the beam injector for the Relativistic Heavy Ion Collider (RHIC) facility, an application that requires its operation only a fraction of the 168 calendar hours each week. At the present time, this fraction is about 60% and it is our goal to decrease this to 40% over the next few years as the commissioning of the many different operating modes of RHIC is completed. It is possible to use the AGS for a separate user program, such as the E949 experiment, for the remaining ~ 100 hours per week during periods when RHIC runs simultaneously. If RHIC is not running, it is possible to run the AGS alone, but typically at higher per-week cost. Such multi-tasking use for user experiments has already been successfully demonstrated in the earlier data taking for E949. The purpose of this paper is to address the potential impact that E949 operations could have on the RHIC program now in progress for DOE-ONP.

To fully assess the impacts, both positive and negative, of E949 operations on the RHIC program, DOE-ONP included possible E949 operations in the review headed by DOE's Daniel Lehman of the potential impacts of RSVP on RHIC. The formal Charge to the reviewers, along with additional guidance for the objectives of the review, is provided as Appendix I of this paper for the convenience of the reader. This paper itself meets one of the requirements of the review guidance and includes a cost and funding spreadsheet that constitutes another of these requirements. It is anticipated that NSF program officers will attend the review as observers.

Finally, in this Introduction, we provide a brief guide to the main content of the paper.

In Section 2, we provide a brief synopsis of the science objectives, experimental approach, and plans for the operation of E949 if it is approved and funded. Details of these plans are provided in the form of web references in Appendix III.

In Section 3, we briefly discuss the plans for oversight and review by the NSF and DOE, as they are presently understood.

In Section 4, we discuss the specific impacts, positive and negative, that have transpired during the commissioning and operations periods for E949 or could transpire during future operations for E949. Although there are interactions between E949 and RHIC during the repair and upgrade phase (via the involvement of C-AD staff), these are minor; the simultaneous machine-use periods are the most important for this review.

In Section 5, we discuss the specific impacts on RHIC during the repair/upgrade and decommissioning/disposal (D&D) phases of the possible E949 experiment. In all cases, RHIC

activities will have priority in this area when potential priority conflicts appear.

In Section 6, we present an overall cost and funding Table to show how possible NSF funding of E949 relates to the E949 work provided by BNL as well as for experimental operations of the E949 experiment. This cost/funding Table was also required for this review in the guidance from DOE.

The material in all these sections will be presented orally during the review and opportunities provided during the parallel sessions to explore issues and questions of the reviewers.

2. **Proposed E949 Program**

Quark mixing and CP violation are among the most intensely investigated topics in particle physics. The E949 experiment is exploring one of the only weak interaction processes involving quarks for which the theoretical ambiguity is small: measurement of the decay $K^+ \to \pi^+ \nu\nu$. E949 has the proven ability to reach an order of magnitude greater sensitivity than achieved by the successful precursor experiment E787 which discovered this process. If the Standard Model (SM) prediction is confirmed, E949 will measure the mixing between t and d quarks $|V_{td}|$ to better than 30% precision. This will provide a direct comparison to the same quantity to be measured by CDF through B_s mixing, giving one of the most stringent tests ever of the SM.

E787 presented evidence for the decay $K^+ \to \pi^+ \nu\nu$ based on the observation of two clean events with an expected background of 0.15±0.05 events. Although the experimental result $B(K^+ \to \pi^+ \nu\nu) = 1.57^{+1.75}_{-0.82} \times 10^{-10}$ is consistent with the SM expectation $B(K^+ \to \pi^+ \nu\nu) = (0.72 \pm 0.21) \times 10^{-10}$, the central experimental value exceeds it by a factor of two. E949 encompasses many improvements to the E787 apparatus which decrease backgrounds and allow for running at higher rates. The possibility of a larger than expected branching ratio gives strong impetus for E949 to fully explore the possibility of new physics, or alternatively, to make a precise measurement of $|V_{td}|$.

The experience of E787 provided a high level of confidence in projecting the sensitivity of E949. This has been borne out by analysis of data from the 12 week run in 2002. E949 employs the full intensity of the AGS proton beam, five times greater than available to E787 and runs concurrently with RHIC. Two options for operation of E949, formulated with BNL management, are considered below. With Option A, at 12 weeks per year over a three-year period E949 will achieve a sensitivity of $(11\text{-}18) \times 10^{-12}$. With Option B, at 18 weeks per year, E949 will achieve a sensitivity of $(8\text{-}14) \times 10^{-12}$. Thus, E949 will reach a sensitivity of approximately an order of magnitude beyond the SM prediction for this process and that achieved by E787.

E949 was granted scientific approval (a `must do' experiment) in 1998 by BNL and in 1999 the DOEDHEP approved funding for E949 to run for three years as `...high priority for the DHEP.' Due to the omission of funds for completing E949 after its initial 12 week run, the E949 collaboration is currently seeking support from the NSF to operate E949 to complete the experiment and realize its goals.

3. Oversight and Management of E949

E949 experimental operations at the AGS will be overseen for NSF, DOE and BNL by the ALD-HENP and these will transpire under the normal BNL operations procedures and controls for AGS experiments. Most of these conduct of operations systems are based in the Collider-Accelerator Department (C-AD) but other BNL administrative units, such as the Physics Department, RHIC-AGS Users Office and the Instrumentation Division are also involved in aspects of the commissioning and data-taking phases of the experiments. There are well-established controls for all aspects of these operations that ensure safe and secure operations plus protection of the environment under a long-established Conduct-of-Operations methodology for C-AD experiments.

4. E949 Commissioning and Operations

The E949 experiment, supported by DOE-DHEP, successfully completed an engineering run concurrent with RHIC operations during the fall of 2001 (September 1, 2001 – November 7, 2001). The beam intensity was limited to 40×10^{12} protons per pulse (Tp) due to a lack of sufficient CAD resources to commission higher harmonic operation of one of the Booster RF cavities (this problem has been solved). During this period two DOE-DNP experiments were run in addition to E949: E930 and E931. Even with several experiments running simultaneously, with the Siemans under repair, and during a year when RHIC operations were still in shake-down mode, reasonable operations were achieved, with up to 80 hours of SEB operation per week. With all of the accumulated experience in RHIC operations achieved since 2001, it is expected that a steady state operation with 100 hours per week should be achievable. Commissioning of high intensity SEB operation will necessarily take time each year that it is attempted; however, with the successful commissioning 40 Tp operations in 2001, there is every reason to believe that commissioning of 65 Tp operations should be achievable.

The plan is to operate E949 concurrent with (and outside if funds and logistics permit) the operation of RHIC during the construction phase of RSVP. This is possible since during a typical 4-hour store, with beams colliding at full energy in RHIC, the injector complex, consisting of the Tandem and Linac pre-injectors and the Booster and AGS synchrotrons, is idle. The 4-hour store length is presently determined by Intra-Beam-Scattering (IBS) that leads to a typical Au-Au luminosity lifetime of about 2 hours. A future luminosity upgrade of RHIC consists of full-energy electron cooling to counteract IBS (RHIC II). Even in this case the store length will be about 4 hours due to direct "burn-off" of the gold beam at the four RHIC collision points.

At the end of a store the super-conducting RHIC magnets are ramped to injection energy and each of the two RHIC rings is refilled with up to 111 bunches. Even though the actual filling time is only about 5 – 10 minutes a full hour is allocated to allow for tune up of the injector performance.

The AGS complex has long had multi-user capabilities even before its use as RHIC injector. This capability allowed for fast and accurate switching of all control points of the complex between four different modes of operation. The switch can be accomplished between two AGS or Booster pulses and is therefore referred to as pulse-to-pulse (PPM) modulation. Each mode of operation is tuned up to maximum beam performance and then loaded either synchronously (repetitive) or asynchronously (on demand). This feature has been used routinely and very successfully for e.g. early RHIC commissioning during AGS Slow-Extracted Beam (SEB) operation, g-2 Fast-Extracted Beam

(FEB) commissioning during SEB operation, and most recently for beam operation for the National Space Radiation Laboratory (NSRL) during AGS set-up for RHIC operation.

More recently a somewhat expanded "mode switching" was developed that allowed slower devices such as stripping foil changers and solid core magnets to be included. In this case a script automates the whole switching process that now typically takes about 2-5 minutes depending on the slowest device. This "mode switching" has successfully been used to operate high intensity SEB for E949 as well as polarized proton commissioning in the AGS during RHIC stores. This is the mode presently planned for the operation of E949. We are investigating the possibility of implementing faster PPM switching between high intensity E949 running and RHIC injection to further increase the availability of the AGS for E949. This may be particularly important if even shorter RHIC stores are needed.

Mode switching between high intensity E949 running and polarized proton injection into RHIC will take about 10 minutes because the superconducting Siberian snake in the AGS will have to be ramped to zero field for high intensity beam. However, RHIC stores with polarized proton collisions are not limited by IBS and therefore have much longer stores of about 8-10 hours.

The AGS complex has operated at the world's highest proton intensity of $7x10^{13}$ protons per pulse and has still maintained an activation level that allowed maintenance by hand. This was achieved by limiting losses and proton throughput so that the machine activation stays below a pre-set level. It is planned to continue this policy, as was done for the first run of E949 in 2002 and is expected for any possible future runs of E949. Nevertheless, there will be enhanced activation of the accelerator components of the Booster and AGS and "cool-off" periods of a few hours will be needed before particularly activated areas can be accessed. This can impact RHIC operations if emergency repairs of the injector are required. On the positive side, due to the continuous operation of the injector complex any equipment failure will be detected and corrected immediately instead of only by the time of the next filling period for RHIC leading to better injector uptime for RHIC.

Reduced lifetime due to radiation damage of especially exposed components will be mitigated by preventive replacement. It is expected that one or two Booster magnets will have to be replaced every year.

5. E949 Upgrades/Repairs and D&D

a. AGS

There are no construction items for the injector complex.

b. E949

E949 was approved by the DOE Division of High Energy Physics on August 26, 1999. The construction of the detector and upgrades to the beam line were completed in 2001. The new proposal to NSF includes several repairs and upgrades to both the beam line and detector. The manpower and material for the repairs to the beam line, estimated at $628K, will be the responsibility of NSF. The work is expected to take five months and will be scheduled so as not to impact RHIC operations. The manpower for detector preparations does not involve any DOE-NP funded personnel.

c. E949 D&D

The D&D plan for E949 is to restore the AGS floor to the conditions existing at the end of the 2002 run sponsored by DOE within a reasonable number of years after the end of experiment operations. It is recognized that a 2-3 year "cool-down" period will be required before D&D can begin.

Since E949 is an operating experiment the NSF responsibility for D&D will include only those items added subsequent to the end of the DOE funded segment of operations. This includes new front-end magnets, a refurbished beam separator and a new beam dump. The estimated costs are given in Section 6c below.

6. E949 Incremental Costs and Funding

a. Overall E949 budget considerations and Operations Cost

The cost to operate the E949 experiment is calculated incremental to the costs of RHIC operations. This incremental and cost sharing model had been the case at the AGS, for the period of 1986-2002, between HEP and NP during the pre-RHIC and into the RHIC era. AGS fixed target operations costs are based on past experience with HEP and NP experiments as well as NASA, NNSA and BES experiments. The cost estimates to follow cover the various running scenarios envisioned for the E949 experiment and are based on the following assumptions.

- AGS slow extracted beam (SEB) operations E949 will run concurrent with RHIC collider operations when possible. Running concurrent with RHIC operations will require base personnel support for the AGS fixed target operation. Without base support short runs are costed on a per hour basis (full cost recovery) for personnel and materials and scheduled outside of RHIC operations. Such runs are considered on a case-by-case basis and carried out only if the impact on RHIC shutdown work is minimal.

- During RHIC injection all other machine operations will cease, so as to allow full attention to this process. This mode of operation was commissioned in FY 2001 with the successful operation of the AGS as a heavy ion injector for RHIC and for high intensity proton (SEB) for three AGS fixed target experiments. Switching times of order 15-30 minutes have been demonstrated. This should result in about 100 hours per week for SEB.

- The NSF HEP program operations costs are calculated as an incremental cost to the base NP support of RHIC injector operations.

- The NSF will incrementally support the power costs for SEB, beam transport and experimental area operations. The standby AGS power consumption of 7 MW (RHIC Operating with protons) or 5 MW (RHIC Operating with HI) is billed to RHIC operations. The additional flattop, extraction system, beam transport and experiment power is billed to the NSF. Power costs are billed on an actual use basis whereas other costs, personnel and materials, are billed according to previously established average costs. Power costs are assumed to be fixed at $55/MWhr through July 2005 and $85/MWhr thereafter. Our present NYPA contract will

expire in July 2005 and $85/MWhr is the guidance we've been given by the laboratory. Note this rate is still significantly less than the Long Island homeowner pays.

- Most accelerator manpower is covered by RHIC operations. Main control room operations is sufficient to cover SEB operations during RHIC collision operations. There are no manpower charges except for an incremental effort to support the SEB extraction system.

- The RHIC program does not support any manpower for AGS experiments. NP has not budgeted test beam support for its own program. All experimental area manpower support will be billed to the NSF. The manpower costs that are shown below consist of a base manpower level that supports the extraction system, switchyard transport, primary proton transport and the primary target area. The incremental manpower cost for an experiment is explicitly identified. The additional HEP manpower is matrixed into the Collider Accelerator Department staff.

- M&S, DTS and special procurement for AGS/Experiment concurrent with RHIC operations are charged incremental to RHIC. It is assumed E949 is on 80% of the time (i.e. off during RHIC fills).

- M&S, DTS and special procurement for E949 operation outside of RHIC operations are fully charged (no RHIC help). Only shift differential (15%), however, is charged for accelerator machine operations staff.

- Capital construction costs are fully borne by the NSF. This includes any experiment upgrades/repairs and beam line upgrades/repairs.

The RHIC schedule for FY2005 and beyond is not set. The optimal RHIC operations plan calls for 37 weeks per year of RHIC cryogenic plant operation but the required funding to do this has not materialized. Consequently, for this exercise, a constant effort 27 weeks per year RHIC running scenario is assumed. Of the 27 weeks only 24 weeks are available for RHIC beam activities since 3 weeks are required for cool-down and warm-up of the RHIC magnets. Furthermore, 5 weeks of intense beam development are generally required to establish stable physics running conditions for RHIC for each beam species used. So, if one beam species is used by RHIC then that will leave a net 19 weeks available for AGS fixed target experiments and if two beam species are used by RHIC experiments this will result in 14 weeks available for AGS fixed target work. Running outside of RHIC operations is possible and will be considered on a case-by-case basis. The issues are impact on RHIC shutdown activities and possible power curtailment agreements (a summer issue). For planning we assume the E949 experiment could operate for up to about 8 weeks/year in this mode.

The rare kaon decay ($K^+ \rightarrow \pi^+ \nu\nu$) experiment, E949, has been proposed to run during the RSVP construction period. Costs for this experiment are figured incremental to RHIC and RSVP. Some beam development work for RSVP (mostly MECO) will not be compatible with SEB for E949.

The operations costs for E949 are based on the proceeding guidelines and the following:

- RSVP pays for base support for AGS SEB. The assumption is beam development work for RSVP experiments will be scheduled throughout the RHIC running periods and E949 will operate either concurrent with this work or operate during periods RSVP development is off. It is assumed RSVP will provide base support, nominally 16 of the full compliment of 18 FTE's

will be required by the RSVP experiments during the beam development phase of the project (proposed E949 running period).

- 17 FTE base labor is required for E949 operations. It is assumed that E949 will operate with second priority to RSVP needs and will share the 16 FTE's paid for by RSVP. One additional FTE is then needed to complete the 17 FTE complement for E949.

- M&S, DTS and special procurement for E949 is charged incremental to RSVP operations, RHIC operations or RHIC shutdown as appropriate.

- In the year preceding the start of the run, preparatory work for the experimental area must be completed. Work includes the AGS, switchyard and beam transport as well as work to retrofit the LESB3 shielding for the refurbished (to be completed) LESB2 separator, install the new Q1 Q2 doublet, build a new target, repair beam instrumentation, shake-down the switchyard and beam transport and deal with beam dump issues. Funds for this work must be received at least 5 months before the start of the E949 run.

A breakdown of costs to run E949 follows:

E949 Operations Cost, FY 2003 $'s with Full BNL and NSF Indirects
(based on p. pile 4 Dec 2002 memo, subject: AGS SEB Operations Cost Update - E949 and RSVP - *with modifications*)
The present NYPA contract expires in July 2005 and energy costs are expected to increase and is reflected here

Assumed Energy Cost	$ 85	per MWhr	

Fixed Costs		**Cost with NSF Indirects**	
Personnel Costs	**FTE's**		
Base FTE	12	$ -	RSVP pays (shares with E949)
E949 FTE	4	$ -	RSVP pays (shares with E949)
E949 FTE	1	$ 190,255	
Total	**17**	**$ 190,255**	

	Costs per week (these costs scale with running weeks)				
Booster and AGS Accelerators	**w/o RHIC**	**w/RHIC HI**	**w/RHIC pp**	**Concurrent with RSVP & RHIC**	**Concurrent RSVP RHIC off**
DTS	$ 28,447	$ 14,223	$ 14,223	$ -	$ -
MSTC	$ 80,284	$ 40,142	$ 40,142	$ -	$ -
Special Procurement	$ 22,388	$ 11,194	$ 11,194	$ -	$ -
Shift Differential (5 seats)	$ 13,161	$ -	$ -	$ -	$ -
Booster and AGS sub-total	**$ 144,963**	**$ 65,559**	**$ 65,559**	**$ -**	$ -
On time% (determined by RHIC needs)	100%	80%	80%	80%	100%
Booster and AGS Cost per week	**$ 144,963**	**$ 52,447**	**$ 52,447**	**$ -**	$ -
Linac					
DTS	$ 6,638	$ 6,638	$ 3,319	$ -	$ -
MSTC	$ 11,574	$ 11,574	$ 5,787	$ -	$ -
Special Procurement	$ 47,458	$ 47,458	$ 23,729	$ -	$ -

Linac Sub-Total	**$ 65,670**	**$ 65,670**	**$ 32,835**	**$ -**	$ -
On time%	100%	100%	80%	100%	100%
Linac Cost per week	**$ 65,670**	**$ 65,670**	**$ 26,268**	**$ -**	$ -
AGS SEB exp area MSTC	**$ 21,044**	**$ 21,044**	**$ 21,044**	**$ 21,044**	**$ 21,044**
Experiment E949 MSTC	**$ 16,835**	**$ 16,835**	**$ 16,835**	**$ 16,835**	**$ 16,835**
Power (MW)					
Base (experiment power that's always on)	1	1	1	1	1
Accelerators	12	7	7	0	0
Linac (always on)	2	2	0	0	0
Experiment (total)	2.8	2.8	2.8	2.8	2.8
Power Total	**16.8**	**11.8**	**9.8**	**2.8**	**2.8**
Power Cost					
Cost/MWhr	$ 85	$ 85	$ 85	$ 85	$ 85
On time	100%	80%	80%	80%	100%
Sub-Total	**$ 239,904**	**$ 143,371**	**$ 114,811**	**$ 34,843**	**$ 39,984**
3% FCR (NSF)	$ 7,197	$ 4,301	$ 3,444	$ 1,045	$ 1,200
Power Cost Total	**$ 247,101**	**$ 147,672**	**$ 118,256**	**$ 35,888**	**$ 41,184**
Total Experiment Cost/week that scale	**$ 495,613**	**$ 303,669**	**$ 234,850**	**$ 73,768**	**$ 79,063**
Example Total Cost (10 weeks)					
Labor	$ 190,255	$ 190,255	$ 190,255	$ 190,255	$ 190,255
Other	$ 4,956,133	$ 3,036,690	$ 2,348,502	$ 737,680	$ 790,630
E949 Total Operations Cost	**$ 5,146,388**	**$ 3,226,945**	**$ 2,538,757**	**$ 927,935**	**$ 980,885**

Manpower

The base manpower estimate is comprised of the following:

	FTE
Physicist	1
Engineering (mechanical, electrical)	1
Controls	0.5
Instrumentation	1
Vacuum systems	0.5
Magnet systems	1.5
Power supplies	1.5
Utilities (power, water, AC)	2
Extraction systems	1
ES&H, QA, Admin, training (org. burden)	0
Shift operations	2
Total	12

E949 manpower support

Physicist, engineering	1

Beam Separator engineering, technicians	2
Technicians (insert., vacuum, magnet etc.)	2
Total	5

b. E949 Costs

The cost of E949, described in this section, is as was proposed to the NSF in October 2003. The assumptions underlying this cost differ from other parts of this document, they include: 24 week RHIC runs with two different ion species, RSVP operations without simultaneous E949 operations, and power costs based on electricity rates in effect until July 2005.

The cost basis of E949 as submitted to the NSF assumes that RHIC will continue to be operated by DOE-ONP for approximately 24 weeks per year. The full 3-year cost for E949 operations concurrent with RSVP pre-operations is summarized here.

Year	Option A		Option B	
FY2004	$0.8	preparations	$0.8	preparations
RSVP yr#1	$3.7	12 weeks	$6.2	18 weeks
RSVP yr#2	$3.7	12 weeks	$6.2	18 weeks
RSVP yr#3	$3.7	12 weeks	$6.2	18 weeks
Total	$11.9	36 weeks	$19.4	54 weeks

E949 Cost. All numbers are in millions of FY2003 dollars. Costs for the first year include beam line repair and upgrades and detector maintenance. Costs for subsequent years, assume runs overlapping with RHIC and RSVP for 10 weeks per year. Additional running would be outside of RHIC and RSVP at a higher cost per week. All costs include detector operations. No D&D costs were included.

Two options are presented: Option A, at 12 weeks per year, is near the minimum reasonable number of weeks per year given startup overhead, and would approximately double E949's data set in the first year of operation; Option B, at 18 weeks per year, is near the maximum number of weeks per year available to E949 under the assumptions above. For either option, $800K is needed for preparation work. The total number of weeks of running for E949, including the 2002 run, under Option A is 48 weeks and under Option B is 66 weeks. The choice of options can be informed by results from E949's 2002 run, and could be changed for the out-years.

AGS Operations:
The cost basis for HEP operations of the AGS for E949 or RSVP is outlined in the memo from Phil Pile of the Collider-Accelerator Department (CAD) dated December 4, 2002. The power and M&S costs are incremental to the operation of the AGS complex in support of a RHIC heavy ion program supported by the DOE-NP. The labor cost to support the extracted beam and any experiments is fixed, independent of the number of weeks of SEB operations. The M&S costs for accelerator operations are billed incrementally to RHIC operations. The M&S for extraction, switchyard, primary proton transport and experimental operations are fully billed to the SEB user. These M&S costs are fixed under the assumption of RHIC heavy ion operations, and based on past SEB operations experience. The power costs are for incremental power usage in support of SEB operations. RHIC covers 5 MW of standby power consumption and the remaining power usage for the accelerators, beam transport and the experiment are billed on an `as used' basis to the SEB user. The cost in the table is for a power cost of $55/MW-hr, which is at the high end of E949 experience (2002 power costs ranged from $48-55/MW-hr), although the current BNL contract for power is set to expire in July 2005, with an expected increase to $85/MW-hr.

The detailed cost basis for E949 running concurrent with RSVP pre-operations is provided in the memo from Phil Pile dated October 9, 2003. In the proposal to NSF we assume that NSF is providing $3.1M of base labor costs as part of the RSVP program (16 FTE's of technical support to run a Slow Extracted Beam program), leaving a labor cost of $197K/year (1 FTE) to be supported to run E949. The cost to run E949 with RHIC running heavy ions and no other users is $220k/week ($89K/week of power costs, and $130K/week of expected M&S costs). The comparable cost of operation concurrent with RHIC polarized proton (pp) running is less, $145K/week ($74K/week for power and $71K/week for M&S). For periods of time where E949 can run parasitically to RSVP the cost is $65K/week. For E949 to run outside of RHIC operations the cost is $396K/week.

Detector Operations:
The detector operations costs have two components: 1) labor, and 2) M&S. The manpower to support E949 operations is dominated by pre-run preparations and therefore does not have a strong dependence on the length of the run (12 weeks vs. 18 weeks). This manpower effort is 2.2 FTE's ($305K) for Option A and 2.5 FTE's ($350K) for Option B. The M&S costs (data media, gases and other consumables, maintenance contracts, and repair and replacement of electronics and detector hardware) scale more closely with the number of weeks of operations. They are estimated at $305K for a 12 week run and $360K for an 18 week run. The total cost for detector operations is $610K($710K) for Option A(B).

Startup Costs (FY 2004):
This budget includes $628K in the first year for repairs necessary to bring the beam line into working order before the start of operations for the E949 experiment (see memo from Phil Pile dated October 9, 2003). This includes $100K for repairs to Separator #1, $50K for installation of Q01-02, $175K for beam line instrumentation and $300K for modifications to the C-line to reduce the radiation exposure to LESB3. At the end of E949's last run in 2002 Separator #1 was operating at a HV of 250 kV, as compared to the expected value of 600 kV (achieved during E787 running and during the E949 engineering run in 2001). Repair work was begun in the summer of 2002, before being halted due to lack of funds at the end of FY2002. Given the impracticality of replacing the Q01-02 magnets during a run, it is felt to be prudent to replace them before running again. The radiation levels in LESB3, particularly around the first separator, can be reduced by the installation of a beam dump in the C-line downstream of the C-target, replacing the magnets and collimator currently installed. This budget includes $175K to bring the detector into working order, including re-installation of the upstream endcap. It is expected that funds received during the first year of this proposal would first be applied for the preparations outlined above and would take five months to complete (driven primarily by the separator repair schedule).

Years 2-4 Costs:
The second through fourth year of this proposal are costed separately for Option A and Option B. Option A is cost effective, running for 12 weeks per year and reaching 7 SM events (75% of Option B) for only 60% of the cost, by minimizing the more expensive running outside of RHIC operations. Option B provides the full experimental sensitivity of 10 SM events, running for 18 weeks, which is likely to be the maximum number of weeks possible per year. We have conservatively estimated that DOE-NP will fund at least 24 weeks of RHIC operations per year (the original RHIC operating plan calls for 37-3=34 weeks per year). We have made an additional conservative assumption that RHIC will require setup time for two ion species each year (meaning 2x5=10 weeks of setup per year). Our assumption of 10 weeks of E949 running within the RHIC envelope, in addition to RSVP running, is based on a bottom up review of RSVP beam development effort (see October 9, 2003 memo). We have

conservatively costed these 10 weeks under the assumption that none of this time is concurrent with RSVP running with its lower cost profile.

Both options have a fixed AGS labor cost of $197K/year and include 10 weeks of E949 operations with RHIC (all 10 weeks are costed without concurrent RSVP operations) at $2.08M, for a total AGS cost of $2.275M for 10 weeks. In option A we add 2 weeks without RHIC for $792K, for an AGS cost of $3.07M for 12 weeks of E949 operations. I and in Option B, we add 8 weeks without RHIC, or $3.168M, for an AGS cost of $5.45M for 18 weeks of operations. Detector operations require $610K per year for Option A and $710K per year for Option B. The total cost per year is $3.68M for Option A and $6.16M for Option B.

c. E949 D&D Costs

The costs below are in millions of FY 2003 dollars, fully burdened

Experiment	**Estimated D&D Cost**
E949	$0.7
Contingency	$0.2
Total Estimated Cost	$0.9

Appendix I – RSVP/E949 Review Charge and Instructions from DOE

I. DOE ONP Charge Document of November 24, 2003

United States Government **Department of Energy**

memorandum

DATE: November 24, 2003

REPLY TO ATTN OF: Office of Science

SUBJECT: DOE Review of the Rare Symmetry Violating Processes Project Activities at Brookhaven National Laboratory

TO: Daniel Lehman, SC-81

I would like to request that your office conduct a review to assess the impact of the proposed Rare Symmetry Violating Processes (RSVP) project on the current Relativistic Heavy Ion Collider (RHIC) activities at Brookhaven National Laboratory (BNL).

As you know, the Office of Science (SC) Nuclear Physics (NP) program supports the operations of the RHIC facility at BNL. The National Science Foundation (NSF) is proposing to construct and operate two experiments, the RSVP project, that would utilize the Alternating Gradient Synchrotron (AGS) facility which is the injector for and an integral component of the RHIC facility. The SC Nuclear Physics program welcomes the opportunity to make available the capabilities of its facilities for meritorious non-NP activities, as long as these activities do not have a negative impact on the facility's ability to successfully carry out the primary mission for which it is funded.

A Memorandum of Understanding between NSF and DOE is in preparation to define the scope and the roles and responsibilities of the agencies. The high scientific merit and priority of RSVP have been ascertained and well documented by peer-review, including the NSF National Science Board. The NSF proposal includes funding to construct and commission these experiments, including the incremental operating costs for their research program. In order to proceed, the Nuclear Physics program needs to understand the impacts related to mutual compatibility of the construction, commissioning and operations of RSVP and RHIC's nuclear physics mission, both short- and long-term.

In this context, I request that your office conduct a review of these impacts. In particular, the review committee should assess the risks and impacts (both positive and negative) of the proposed RSVP construction project and RSVP operations on the RHIC accelerator complex and RHIC nuclear physics program at BNL, including other ongoing work-for-others activities that utilize the RHIC accelerator complex such as the NASA Space Radiation Laboratory. This assessment should include NSF expectations of beam time for the RSVP program and identify the incremental costs to NSF for this running time.

I have asked Jim Hawkins of my office to work with you on this review. I would like the review to take place by the end of January 2004 and would appreciate receiving your committee's report within 60 days of the review's conclusion.

[SIGNED]

Dennis G. Kovar
Associate Director of the Office of Science
for Nuclear Physics

cc: Tom Kirk, BNL
Peter Paul, BNL
Michael Holland, BAO
Joe Dehmer, NSF
Marvin Goldberg, NSF
Robin Staffin, SC-20
Aesook Byon-Wagner, SC-20

II. Additional Material Supplied by DOE Office of Nuclear Physics, December 11, 2003

Subject: RSVP Review
Date: Thu, 11 Dec 2003 18:05:59 -0500
From: "Kovar, Dennis" <Dennis.Kovar@science.doe.gov>
To: "Tom Kirk (tkirk@bnl.gov)" <tkirk@bnl.gov>
CC: "Lehman, Daniel" <Daniel.Lehman@science.doe.gov>,
"Steadman, Stephen" <Stephen.Steadman@science.doe.gov>,
"Hawkins, James" <James.Hawkins@science.doe.gov>,
"Derek I. Lowenstein (lowenstein@bnl.gov)" <lowenstein@bnl.gov>,
"Goldberg, Marvin" <mgoldber@nsf.gov>,
"Brad Keister (bkeister@nsf.gov)" <bkeister@nsf.gov>,
"Byon, Aesook" <Aesook.Byon@science.doe.gov>

To: Tom Kirk
From: Dennis Kovar
Subject: RSVP Review

Regarding the upcoming Lehman review of the impacts and incremental costs of the RSVP project, BNL needs to provide a written response by Wednesday, January 12, 2004 addressing the November 24, 2003 charge letter to Daniel Lehman. This written response will be reviewed and evaluated by the review committee during the review scheduled for January 27 and January 28. All supporting documentation should also be available by January 12, including the MECO and KOPIO management plans, documents that identify all resources (costs, funding, and manpower) required to support MECO and KOPIO, and a decommissioning and disposal (D&D) analysis of the work that will need to be accomplished at the completion of the RSVP program. Because NSF is also considering sponsorship of the continuation of AGS experiment E949 under equivalent administrative conditions, we intend to consider the RHIC program impacts of this experiment in the same review, using the same tools. We, therefore, ask that the equivalent E949 documents be made available to the committee.

The response should cover the RSVP project and operations program which includes the experiments KOPIO, MECO, and E949. In addition, the response should include a spreadsheet that captures all of the relative incremental yearly costs associated with the life-cycle cost of the RSVP project and the AGS. These incremental costs should include appropriate items associated with commissioning, operating, maintenance, capital reinvestment, waste disposal, and final disposition (D&D). As per the draft MOU between DOE and NSF, the cost to decommission, decontaminate, and deconstruct this project will be assessed in yearly amounts over the length of the planned operation, with funds placed in a suitable escrow account.

If you have any questions, please contact Stephen Steadman or Jim Hawkins within my office.

Cc:
Daniel Lehman
Stephen Steadman
James Hawkins
Marvin Goldberg
Derek Lowenstein
Brad Keister
Aesook Byon-Wagner

Appendix II – Agenda for the Review
(Revised January 25, 2004)
DOE Review of the RSVP Activities at BNL
Brookhaven National Laboratory
January 27-28, 2004

Tuesday, January 27, 2004 **Berkner Rm. B**

08:00 am	DOE Executive Session	
	Remarks	M. Holland
08:30 am	Welcome	P. Chaudhari
08:40 am	Overview of RSVP Project	J. Sculli
09:00 am	RSVP at BNL	T. Kirk
09:15 am	Work for Others (WFO) at AGS – NSRL Experience	D. Lowenstein
9:45 am	Coffee Break	
10:00 am	DOE-BAO Site Office Oversight	R. Desmarais
10:15 am	RHIC/RSVP Experimental Ops. & RSVP Installation	P. Pile
11:00 am	RHIC/RSVP Accelerator Ops. & RSVP Modifications	T. Roser
12:00 pm	DOE Working Lunch	**Berkner Rm. A**

1:00 pm Parallel Sessions *

Experiments/Beamlines Topics **Berkner Rm. B**

Topic	Discussion Leader
- Construction/Installation/D&D Periods	Al Pendzick
- E949 Preparations/D&D	Al Pendzick
- RHIC-RSVP Interactions (Benefits & Risks) (this discussion includes Accelerator group)	Phil Pile

Accelerator Topics **Berkner Rm. C**

Topic	Discussion Leader
- RHIC operations performance and plans	Wolfram Fischer
- Extraction and primary beam transport commissioning	Kevin Brown
- Machine R&D for RSVP	Leif Ahrens
- AGS operations with RHIC	Kip Gardner

* Experts from C-AD and the experiments will be present during these sessions

4:30 pm	DOE Executive Session	**Berkner Rm. B**
5:30 pm	Committee Questions for Presenters	
6:00 pm	Adjourn	

Wednesday, January 28, 2004 **Berkner Rm. B**

08:30 am	Answers to Committee Questions	
09:00 am	DOE Executive Session	
12:00 pm	DOE Working Lunch	**Berkner Rm. D**
1:00 pm	DOE Executive Session (Cont.)	
02:00 pm	Closeout With BNL and RSVP Management	
02:30 pm	Adjourn	

Appendix III – Web References

Supporting documentation, including the MECO and KOPIO proposals, draft technical design reports, floor layouts etc. can be found on the web. The relevant link is given below.

http://www.phy.bnl.gov/review/doe-np_040127

Public Web Pages:

E949: http://www.phy.bnl.gov/e949

K0PI0: http://pubweb.bnl.gov/people/e926/

MECO: http://meco.ps.uci.edu/

RHIC: http://www.bnl.gov/RHIC/

RHIC Luminosity Plot (Present Run):
http://www.agsrhichome.bnl.gov/AGS/Public/QtrReports/rhic_perf/IntegratedLuminositybyYear04.pdf

Appendix IV – Reviewer List

Department of Energy Review
of the Rate Symmetry Violating Processes (RSVP) Project
January 8, 2003
REVIEW COMMITTEE PARTICIPANTS

Department of Energy

Daniel Lehman, DOE/SC, Chairperson	**301-903-4840**	**daniel.lehman@science.doe.gov**
Steve Tkaczyk, DOE/SC	301-903-3288	steve.tkaczyk@science.doe.gov

Subcommittee 1: Experiment

*Richard Ehrlich, Cornell	607-255-4154	rde4@cornell.edu
Stephen Gourlay, LBNL	510-486-7156	sagourlay@lbl.gov
Karol Lang, U. of Texas	512-471-3528	lang@hep.utexas.edu

Subcommittee 2: Accelerators

*Peter Limon, Fermilab	630-840-3340	pjlimon@fnal.gov
Robert Mau, Fermilab	630-840-4429	mau@fnal.gov

Subcommittee 3: Management

*Ronald Lutha, DOE/FAO	630-840-8130	ronald.lutha@ch.doe.gov
Bob Macek, LANL	505-667-8877	macek@lanl.gov
[Peter Limon, Fermilab]	630-840-3340	pjlimon@fnal.gov

Observers

Dennis Kovar, DOE/SC	301-903-3613	dennis.kovar@science.doe.gov
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Mark Coles, NSF	703-292-4432	mcoles@nsf.gov
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* Subcommittee Chairperson
[ ] Part-time Subcommittee Member