Response to Recommendations from the DOE-SC CD-1/3A Review of sPHENIX

The Super Pioneering High Energy Nuclear Ion Experiment (sPHENIX) MIE was reviewed May 23-25, 2018 by a committee organized and charged by the DOE Office of Project Assessment. A main element of the charge to the committee was to determine if sPHENIX was ready for CD-1/3A approval. The committee's report concluded that sPHENIX was ready for CD-1/3A approval pending the closure of four recommendations:

1. Revise the EMCal KPP to better reflect actual experience with the uniformity SiPMs and Blocks.
2. Finalize the risk based contingency and funding profile.
3. Analyze the risk to the Project from the large amount of contributed labor.
4. Review and update the risk register.

The sPHENIX Project team has considered and addressed each recommendation. The responses are included in this document and associated documentation is included where applicable. In addition, the committee had an actionable comment in the report, "The current plan for early procurement of the fibers and the tungsten powder involves phased procurements where the second phase requires full CD-3 approval. This introduces a risk should CD-3 not occur as scheduled. Discussions with the Program Office should be held to discuss approval of the full procurement of these two items as part of CD-3A. This does not necessarily impact the funding profile." We have revised the sPHENIX Acquisition Strategy (AS) to reflect the committee's comment by including the full order of scintillating fibers and tungsten powder in the Long Lead Procurement request for CD-3A. The revised AS will be submitted to the sPHENIX Federal Project Director (FPD) and Federal Program Manager (FPM) for approval. The Preliminary Project Execution Plan (PPEP) has been revised to reflect this change. The Advanced Procurement Plans (APPs) have been revised to reflect the plans for procuring all Long lead procurements as phased funded contracts.

Recommendations:

1) *Revise the EMCal KPP to better reflect actual experience with the uniformity SiPMs and Blocks.*

The EMCal group has considered whether their KPP concerning the RMS value of the absolute energy calibration for each sector should be revised down. Upon consideration they have agreed that the Threshold KPP for the EMCAL absolute energy pre-calibration precision should be revised to ≤ 20% RMS from the previous value of ≤ 35% RMS. The Objective KPP is the same as the Threshold KPP. The change in the KPP is included in the revised PPEP. The procedure for obtaining this precision will be a multi-step process.

- We will measure the density of each block very accurately by weighing it and knowing its volume (to order of a percent). The density essentially determines how much energy gets deposited in each block. Once we know this and the sampling fraction, which is the same for each block (or at least each block type), this gives us the conversion from energy deposited to energy observed (i.e., light produced).

- We will measure the light output of each block using a UV light source (which is what the committee suggested), or better yet, possibly with a radioactive source. We will also measure the light transmission through the fibers and determine the number of missing, broken or weak fibers. This will give a measure of the total light output of each block which we can then compare to a standard block for which we know the true absolute light output (photoelectrons/GeV) that we measured using cosmic rays.

- We expect the variation in the light collection efficiency due to the light guides to be minimal. This will be insured by the QA procedure for the light guides.

- The variation in the Photon Detection Efficiency of the SiPM is negligible as determined by Hamamatsu.

- All SiPMs will be measured by Hamamatsu to specify an operating voltage for each device that will achieve a certain gain (~ 2.3×10^5). The SiPMs will then be sorted and pre-selected so that each of the 4 SiPMs on a PCB for each tower will have their operating voltage matched to within 20 mV. This should then insure that the gain of all 4 SiPMs are matched to within a few percent. We also know from our experience in the test beam that this gain is extremely stable over time (except for temperature variations, which we can correct for). The gains should therefore be very well matched on day one prior to SiPM radiation exposure.

By knowing or measuring each of these factors for each block, and then comparing them to the same factors for a set of reference blocks for which we also know the true absolute energy calibration measured using cosmic rays, we should be able to get a reasonable absolute energy pre-calibration for each block. Since each of these five factors individually will be known to probably on the order of 5%, or better in some cases, it is safe to assume that we can determine the absolute energy pre-calibration of each block to better than 20%. We'll also measure some number of blocks during production with cosmic rays just to insure that the procedure is really working and compare to other previous results. This is not as direct a procedure as is used for the HCAL but will work.

2) *Finalize the risk based contingency and funding profile.*

The project team considered the review committee concern that the funding profile for the project as presented at the review was annually distributed without consideration of contingency aligning with the risk distribution. The committee requested a proposed funding profile distributed in alignment with the annual distribution of BAC's obligation profile plus risk.

The project team's analysis of the funding profile included looking at the distributions noted below and the funding amounts for FY17, FY18, and FY19 already fixed and not available for adjustment. FY20 and FY21 are the only years where the funding profile could be adjusted upward. FY22 is mostly schedule contingency and the associated risk registry item for additional marching army. The analysis also did not change Total Project Cost, keeping contingency overall at 30.06% of the "to go" work. The sPHENIX Funding profile shown at the CD-1/3A review, the revised profile based on the committee's recommendation and the Project obligation profile is shown in figure 1. BNL Management agrees with the revised Funding profile shown in the figure and has submitted the new profile to DOE.

Funding Profile for Estimated Total Project Costs in **THEN YEAR k DOLLARS** (escalated & burdened)								
	Prior Yrs	FY17	FY18	FY19	FY20	FY21	FY22	Total
Funding Profile as of CD-1 Review (May, 2018)		**1,613**	**4,460**	**5,660**	**6,560**	**4,610**	**3,647**	**26,550**
Revised Funding Profile submitted to DOE June 2018		**1,613**	**4,460**	**5,660**	**9,524**	**5,080**	**213**	**26,550**
Obligation Proflie - cumulative (w/o contingency)		**429**	**4,177**	**9,608**	**16,641**	**20,505**	**20,531**	**20,531**
Revised Funding Profile - cumulative		**1,613**	**6,073**	**11,733**	**21,257**	**26,337**	**26,550**	**26,550**

Figure 1: The spreadsheet shows the sPHENIX Funding Profile presented at the CD-1/3A review, the revised Funding Profile submitted to DOE June 2018 addressing the review committee's recommendation, the cumulative sPHENIX Obligation Profile and the cumulative revised Funding Profile.

The risk and BAC is copied from the source files into an Excel data table and charted for analysis. The annual distribution of the BAC's obligation profile is derived from the sPHENIX P6 schedule. There are 3 risk categories needed for this analysis: Estimate Uncertainty (EU), Risk Registry items, and Unknown Unknowns (UU). Unknown Unknowns is calculated as follows: UU = TPC - (BAC + EU + Risk Cost Impact). EU is derived by the P6 schedule. Each resource assignment on schedule activities is coded to an EU factor and the EU amount is distributed with the schedule activity dates. Risk Registry items have an assigned start risk realized date and a retirement date in the risk registry. Both of these dates for Risk Registry items are profiled for analysis. UU is distributed relative to the BAC to go distribution in the P6 schedule.

3) *Analyze the risk to the Project from the large amount of contributed labor.*

The sPHENIX MIE depends on two major sources of contributed labor. The collaborating Institutions on sPHENIX provide labor focused on construction of the three new detectors, the Electromagnetic Calorimeter, the Hadronic Calorimeter and the Time Projection Chamber while also contributing broadly to the preparation of sensors, electronics and the data acquisition system. The various operating units in the BNL Nuclear and Particle Physics Directorate: the Physics Department, the Collider-Accelerator Department, the Instrumentation Division and the Superconducting Magnet Division, contribute resources to all aspects of the sPHENIX MIE. Combined the two sources contribute the efforts of scientists doing direct project work, engineers, technicians, software professionals, postdoctoral, graduate students, and a large contingent of undergraduate students.

A loss of a portion of the contributed labor would result in a risk to the sPHENIX MIE, most immediately in loss of schedule, but also potentially arising from the added cost of hiring replacement labor were another source of contributed labor not to be found.

This general risk has been captured in a series of nine entries in the Risk Registry in the case of the University groups. Eight of these deal with the risk to specific WBS areas resulting from the loss of any one of the various types of contributed labor at a single University. The ninth addresses the risk arising to the sPHENIX MIE if one of the contributing university groups no longer had a source of research support funds or left the collaboration for any reason.

Of the eight University-specific risks (Nos. 47-51 and 53-55), four deal with loss of undergraduate student productivity at one of the 4 locations producing GEM Modules for the Time Projection Chamber Risk Entries 47-50. This could result from loss of students, or less productivity from inexperienced undergraduate students, for example. The assumed mitigation in these four cases is the same, namely to hire extra skilled technician labor for the 6-month duration of the effort. Risk Entry 51 addresses both the loss of the undergraduate students planned for the University of Illinois to handle filling of the scintillating fibers into the brass screens that form the core of the EMCal Blocks and the possible loss of student labor to work on loading tungsten powder and then epoxy into the Block molds. The mitigation in both cases is to hire skilled technician labor to cover the work planned to have been done by students. The former tasks, fiber filling into the screens, estimated to need some 15 thousand hours of student labor. The powder filling and epoxy loading are estimated to need some 440 hours. The technicians are assumed to have a higher skill level and only need 75% as much time as the undergraduates to do the work.

Risk Entry 53 address the loss of a skilled FPGA programmer at U. Colorado. This task is normally done by an experienced firmware designer, who is usually an engineer. The risk is loss of a currently-supported person and having to replace them with a new hire paid by the MIE.

Risk Entries 54 (Stony Brook) 55 (U Michigan) and 56 (Georgia State U) are similar to Risk Entries 47-51 discussed above and again address loss of local labor and having to replace it with hired technicians. The Stony Brook work is specific to the Time Projection Chamber and is led by an experienced research scientist who would be more expensive than a technician to replace due to the person's extensive skill set and many years of experience building gaseous detectors. The Michigan and Georgia State work are repetitive testing tasks that are planned to be staffed by undergraduates, and again the risk is having to replace them with paid technicians.

The final risk mentioned, Risk Entry 57, is of a different type. The named universities in the other risks mentioned all have ongoing research efforts and expect to participate as members of the sPHENIX scientific collaboration and thus have chosen to contribute to the detector fabrication. Risk Entry 57 addresses the possible complete loss to sPHENIX of one of these groups. This is not thought to be probable but could occur if for example the relevant Principle Investigator was unable to continue work and had to give up the leadership of the group and its support contracts. It then could be necessary to hire replacement labor for all the planned work by that institution. The probability of this occurrence is set as 33% for one and only one of the eight University groups, i.e. 4%. The corresponding unweighted cost impact is the replacement cost of all contributed university labor to the sPHENIX MIE, estimated to be $3.9M.

Given the overall breadth of expertise and experience within the sPHENIX scientific Collaboration, it

is highly likely that personnel with the needed skill set can be found for any given labor shortage at a University, meaning loss of schedule may be more likely. Close contact with all the University groups will be maintained to foresee and address such issues. The funding agencies will be kept apprised of the specific labor contributions planned from University groups. Memoranda of Agreement will be established between the sPHENIX Project and the collaborating institutions to mitigate this risk.

The approach with regards to contributed labor from BNL has been to prepare a series of Memoranda of Agreement with the four BNL units noted above, signed by the respective Department or Division Chair, the sPHENIX Project Director, and the ALD for Nuclear and High-Energy Physics. These documents address the specific work requested, the needed skill set, and the planned resources and schedule. They are tied to specific activities and deliverables in the sPHENIX Resource Loaded Schedule and can be extended by additional Memoranda to address specific tasks or groups of tasks and will be reviewed regularly as the work progresses.

4) *Review and update the risk register.*

The Risk Registry has been updated to address comments and recommendations from the CD-1/3A review committee. It has also been updated to the current sPHENIX Project risk status as of June 2018. The only revised item in the risk registry outside of the contributed labor risks that has been described in the response to recommendation 3) is the EMCal epoxy vendor risk. To address a recommendation to consider a risk of losing EMCal epoxy vendor, a new risk has been added to the risk register. The cost impact has been estimated as $10,000 and schedule impact as one month. To mitigate this risk, epoxy from alternative vendors such as EpoTek, Saint Gobain and Stycast will be tested in advance to have an option in the case of losing the currently planned vendor. The updated Risk Registry is provided as a separate document.