Review Response Document from the sPHENIX MIE Associate Director's Review, July 28-29, 2020

Recommendations:

1) Prior to the end of FY20, due to current COVID restrictions and rules in the workplace, the project should re-evaluate potential inefficiencies that might need to be included in the P6 forecast plan.

2) By the end of October 2020, conduct a comprehensive EAC update taking into account future COVID impacts due to social distancing inefficiencies.

3) By the end of FY20, revisit the Risk Register to review the assigned likelihoods and impacts and to check the consistency of assumptions across the project.

4) Prepare a plan by the end of October 2020, with anticipated decision dates, for potential scope opportunities that could be implemented should the project continue to perform well.

Responses:

1) **Due to current COVID restrictions and rules in the workplace, the project should re-evaluate potential inefficiencies that might need to be included in the P6 forecast plan.**

Executive Summary

Every subsystem in sPHENIX has experienced inefficiencies and/or delays as a result of the COVID-19 pandemic. All laboratories at the Universities and the National Laboratories collaborating on sPHENIX have been shut down for a period, with the shortest shutdown being 2 months. In contrast, vendors under contract at the time of the shutdown in March 2020 have been able to continue operations with only minimal interruption. Workspaces have been re-arranged at the several laboratories, personnel access rules have been updated and those changes implemented, and work has been re-started. A measure of the added time and effort needed to complete the sPHENIX production is thus now in hand. Most subsystems have been able to preserve non-zero float against their delivery date and can accommodate even a 20% added inefficiency without consuming all of their individual float. The EMCal construction has been on the critical path since the approval of the sPHENIX MIE project, and as expected remains on the critical path. If a 20% added inefficiency occurs for the EMCal construction, the finish date will delay by 50 days. This work on the EMCal would still be complete more than 8 months before the proposed PD-4 date for the sPHENIX MIE project. Importantly, such a further inefficiency could just be accommodated in the installation schedule foreseen at present for sPHENIX in the 1008 complex.

We address below, by subsystem, both potential inefficiencies as well as those COVID-related delays and inefficiencies which have already occurred, as well as the measures we have taken to address them.

WBS 1.1 Management

All managers are working from home and making occasional visits to BNL. Meetings via Bluejeans, Zoom and MS-Teams are held regularly. The planned review schedule from P6 is being followed, review issues are being addressed and procurements are being submitted regularly to Procurement. Monthly EVMS status reporting and variance tracking has been done every month, project reports are being prepared every month, and meetings to report status have been held with BNL management and DOE representatives every month. Personnel interviews are being carried out, remotely if needed, and new hires have been brought in for DAQ, EMCal, infrastructure, and installation work. The tasks being covered by these new hires include including both technical work, computer programming, and engineering and design work.

One case of COVID did occur among the project management; the employee was at home and was able to continue at somewhat reduced effort for 2 weeks and has since returned to work full time.

Site visits to vendors are less frequent as a result of COVID due to our own self-isolation coupled with vendors' desires to control their workspaces so that they may remain open for business. This has been addressed by increased frequency of teleconferences and videoconferences with vendors. Site visits where required for equipment acceptance prior to shipping have been negotiated.

Engineering and design effort has been continued at a good pace after an initial adjustment to ensure all persons had adequate off-site access to engineering and design tool. Some large analysis jobs must run on licensed machines at BNL. Coordination among the engineers has been made to ensure this particular work is done.

A liaison has been designated for sPHENIX personnel needing access to the BNL site. The helps to control the total number of people on site at once and to control laboratory occupancy throughout the workday as well as to coordinate with needed services at BNL.

We note that in the following descriptions, float is quoted relative to the MIE early completion date of January 2022. This date in turn has eleven months float with respect to the MIE PD4 date. Specific remarks regarding float with respect to the installation timeline in the WBS 2.x effort are included in the writeups by subsystem

WBS 1.2 TPC

CERN had to close operations due to COVID, which meant the work on manufacturing the GEM foils for sPHENIX was suspended. The shop at CERN has since re-opened. We negotiated with CERN that sPHENIX would support an additional technician to produce the GEM foils in order to maintain our baseline schedule for GEM foil completion, which has a finish date in March 2021. Two months along this arrangement is working and we are seeing GEM foils delivered as requested. CERN has noted that a third technician can be added if needed to address any future schedule slippage. We are monitoring this in coordination with CERN. At present this arrangement preserves the baseline delivery schedule for the GEM foils.

GEM framing is commencing at all four sites, Wayne State U, Vanderbilt U, Weizmann Institute and Temple U. All sites depend on having their laboratories open and having research staff and students allowed to work. To date work has progressed as planned, with GEM foil arrival being the pacing event, as planned. These tasks presently have 100 days float in the P6 progress file. Each needs to produce 24 framed GEM foils over 7 months, which can be maintained with current workforce. If one site needed to close, it would be possible to move the work to another site, although this solution is not optimum. If the pace of work slowed by as much as 40% due to COVID, the work could just be completed on schedule.

Stony Brook has had a restriction on the number of undergraduate students allowed on campus. This has affected in particular the construction of the remaining parts of the TPC field cage. We have arranged to support a technician to perform this work and are modifying the contract with Stony Brook. We will monitor the pace of work at Stony Brook and can support additional technicians if this proves necessary, either for countering further COVID-related restrictions or if we learn that adding only one technician is not adequate to maintain schedule.. We do at present need the Stony Brook site to remain open because that is where we have located all field cage items, facilities for building full GEM modules, and the final TPC assembly site. We maintain 30 working days float for the full sequence of tasks that are planned for Stony Brook.

The TPC front-end electronics is still in preproduction phase, with the first two complete boards assembled and being used to test their operation and noise performance, heat load and required cooling, and failure mode tolerance. Work over the summer has been inefficient due to lab-access issues and the need to coordinate among the limited staff allowed on site. This limit on allowed staff has recently improved to where it is not an ongoing issue. Parts from suppliers have been acquired and the boards plus parts kits have been sent to the assembly house, which is open. Purchase of production quantities of parts is just commencing. To date no supplier has indicated supply problems although lead times quoted in some cases will exhaust all but one month of the free float for the electronics. The board house indicates there are no current production slowdowns, as does the assembly house.

All the SAMPA v5 chips needed for the TPC front-end electronics have been produced and packaged. The group at Lund U has been able to keep their laboratory open and has tested all the SAMPA v5 and is shipping them to BNL. This removes this key source of schedule risk.

The TPC Data Aggregation Modules, DAMs, also colloquially known as FELIX cards, have their preproduction boards under test. This has been slowed by COVID but has produced enough results that the board could be accepted for production use. Procurement of production quantities of parts has begun. To date the supplier do not indicate problems with schedule but again the leadtimes for optical transceiver modules and complex FPGAs will tax the free float for these board. We have planned this production to end in early summer 2021 to allow for possible component or assembly house delays. The TPC final assembly schedule allows for these slowdowns.

We note that the TPC full assembly and system test are presently forecast to be complete 2 months prior to the MIE Project early completion date. However the TPC itself will not be installed into sPHENIX until 6 months after that date, which however would still be 4 months before PD-4. This schedule contingency could be used if the TPC effort were to find itself 'in extremis'.

The EBDC computers needed for the TPC are commercial items. First items have been acquired and are under evaluation to certify that they meet speed and data volume requirements for the TPC. This work can largely be done remotely as long as the computers under test are 'live' in the laboratories at BNL. We currently have 80 days free float for these and to date are told by the vendors that the items remain commercially available with no COVID related delays. Access to BNL, in particular to the Bldg. 1008 Rack Room, to mount and configure these machines for final use will be needed. The testing work is done by a trio of BNL scientists, any one of which could complete it in the case of illness striking one or two of the others.

TPC cooling system parts are to be made in commercial machine shops once cooling tests are complete. These fabrications were delayed 4 months by site-access issues at BNL and availability of the TPC FEE prototype boards over the summer but are now underway. Commercial vendors for the machined parts indicate no current delays; several local vendors exist for these relatively straightforward parts.

TPC gas system work needs access to the 1008 gas pad, which is now possible. The work is a reconfiguration of an existing system used in PHENIX.

The TPC laser system design was slowed by COVID because the group performing it was in the middle of making numerous design decisions when the COVID shutdowns occurred. The design has now matured and been reviewed, and the proponents told to prepare a prototype system, which is being acquired. Vendors are to date indicating no particular delays but not all orders are yet placed and a few custom optical components remain to be ordered. Thus the schedule is still subject to possible delays arising from supply chain of needed items. The assembly and testing of the prototype does require access to BNL laboratories. We maintain 100 days free float for this subsystem. Nearly a dozen BNL and Stony Brook staff and students are involved, with the full design known to the group and carefully documented. A subset consisting of about half of those involved could complete the work, which serves as a contingency in the case of further COVID delays or closures. Presently this work has 80 days float.

WBS 1.3 Electromagnetic Calorimeter

Block construction work at U Illinois had to suspend operations for March and April due to COVID. An overall slip of 2.5 months in the EMCal block production schedule resulted, as reported at the July MIE project review. Progress on EMCal block fabrication in August, September and October did not result in further schedule slippage.

Return to the laboratory at U. Illinois under social-distancing rules was allowed for UIUC staff in May, and students were allowed to return in the summer. It has proved possible to hire enough students and space them out in the laboratory to keep the fiber-filling task current. Prospects remain positive for this as long as U Illinois is allowed to continue operating. Over three dozen students have been trained in this task and are able to adjust their work schedules to allow for COVID rules on the campus and for their classes. To date this can be managed but the added effort to manage it will not cease until the pandemic does likewise.

The vendor for the scintillating fibers did miss one shipment early on due to COVID. They were able to recover this the next month as well as ship the next batch of fibers and have held schedule since. Only four out of 23 total shipments of fibers remain. The vendor indicates they remain open and staffed and does not predict any schedule problems, despite the recent increase in cases in Ohio. We continue to monitor this.

The main work for manufacturing the blocks consisting of filling W powder into a mold containing fibers, adding and curing epoxy, demolding, machining and testing has continued at

Illinois. Some of this has made use of advanced students from a local technical college, which also suspended operations for a time but has since restarted. Several successful recruiting visits to the college have been made to continue this arrangement. To date these arrangements work, but they are susceptible to another COVID-related shutdown just as is the U of Illinois.

Arrangements are being made to supplement the Illinois contract with added technical labor in particular to increase the probability that we can maintain schedule. A worrying number of early blocks produced, nearly 10%, did not pass quality control in the months just before and after the COVID shutdown. We took the time to diagnose these issues, prepare and implement solutions, and monitor the resulting production post-COVID shutdown. The percentage of blocks rejected has fallen to 1% or less and will continue to be tracked. Further additions are being made to the Illinois contract to cover the added cost of these enhanced block production steps going forward. This will require added technical labor at Illinois, which in fact has already been engaged.

The baseline schedule has block production on the critical path. Any delay here directly pushes the end date day-for-day. A 20% increase in the time to produce the blocks for a sector, i.e. from a week to 6 days, moves the early completion date by 50 days. The installation schedule (in WBS 2.x) for the EMCal can absorb one such factor of 20%. A second such factor would push out the completion of installation by 50 days.

The one catastrophe would be the closure of the lab at UIUC. We have no simple solution in that case because the entire factory setup would need to be reproduced elsewhere with an entirely new trained staff. Accordingly, we plan to monitor this and determine if we need to supplement the UIUC labor pool further to hold schedule.

EMCal module production and sector production at BNL was suspended due to COVID for most of 4 months and has steadily resumed as personnel have been allowed to return to the BNL site. The laboratories have been re-arranged to allow social-distancing and the tasks grouped to allow few or even one person to be required in the laboratory at one time. Arrangements have been made to add technical staff, interviews have been held and offers made, to supplement the workforce at BNL; this again will help in maintaining social distance. One step, the gluing of blocks to the supporting “sawteeth”, unavoidably requires multiple technicians to be present and working together. This has now been practiced for the assembly of five sectors and personnel needed for the step reduced to the practical minimum.

The P6 schedule as baselined built in several months of testing and possible work procedure adjustment between the pre-production and the production series of EMCal modules and sectors. This free float has now been consumed by COVID delays and the re-arrangement of workspaces

plus time needed to settle a few final steps in the EMCal sector assembly, in particular cable routing and cooling loop detailed design. The cooling loops are being fabricated in a series of local shops by individuals in order to give some margin against further COVID delays; more than one shop has been qualified in order to reduce the risk from loss of a single-source vendor. Key mechanical parts are being fabricated locally on automated machines that require minimal intervention, again to reduce the need for manpower and physical presence.

The EMCal sector assembly requires various electronic items including the SiPM daughtercards, preamplifiers, interface cards, connectors, thermal monitoring devices, and internal cables. These have all been obtained, with the exception of the final production order of preamplifiers, which has now been awarded. All of these orders and deliveries were accomplished during the COVID pandemic. The testing of these devices has been done at remote sites to minimize personnel needed in one location and to spread the work among multiple vendors and collaborating institutions. The assembly of the sectors can now proceed with these key supplies assured. The pre-production supply of preamps is in hand and tested, and the same vendor will make the production order; this vendor indicates they have not experienced COVID delays and is obtaining the needed parts and boards. We will monitor this but do not anticipate delay at this time from this source.

The assembled EMCal sectors require extensive live testing to obtain baseline operational data and cosmic ray spectra. This has been set up in a manner that, once cables and power supplies care connected to a finished sector, al further operations can be carried out remotely via the Internet. This enables multiple people to be involved at remote sites, reducing the schedule risk and contact risk of having to be present in the laboratory for this lengthy step.

The free float in the EMCal module and sector construction is now gone and the work is on the critical path. Similar considerations apply for any further delay as noted above for the EMCal block work. The installation schedule can absorb 50 days delay before its end date is pushed out, as noted above for the EMCal block work.

WBS 1.4 Hadronic Calorimeter

The Inner HCal sector support assembly and the Inner HCal end rings are both vendor fabrications. They are being bid separately and will be awarded to different vendors to reduce risk from single-supplier shutdown. The engineering, design and production of manufacturing drawings for both were slowed by the COVID shutdown but are now completed. Shops are being

asked about COVID precautions, but as with any private vendor there will be risk from future COVID shutdowns. We have identified multiple vendors if there is an immediate problem with making a contract award. Both items retain more than 60 days float even after these COVID-related delays in completing their designs.

The splice plates needed to assemble the Outer HCal into a linked structure for sPHENIX are under production at a private vendor. No COVID-related delays have occurred. There was an issue with fabrication technique and resultant cracks, but this was resolved, the material replaced, and fabrication method revised, and good production plates produced. The order should be complete in December. This vendor has reported no COVID delays. This work retains 100 days float.

The mechanical sectors for the Outer HCal are all complete and present at BNL. The scintillating tiles for the Outer HCal are just now completing production at that vendor with the last shipment now prepared. That vendor had to shut down for one month after a shipment prepared in late March but did not experience any particular further COVID-related delays and has held to the planned schedule from the CD_3A contract award. The last batch of these tiles arrived at Georgia State U in mid-November, completing this long-lead procurement. Testing of these scintillating tiles is done upon delivery at Georgia State U. There was a delay in this work while Georgia State was shutdown, but students and researchers have since been allowed to return to the laboratories. The laboratories were rearranged to minimize the number of staff present and maintain distancing. The GSU group has completed acceptance testing of all scintillator tiles received from the vendor and then have shipped all these tiles to BNL. The last batch of scintillator tiles has just been shipped form the vendor and should be through testing at Georgia State U by December, several months ahead of when they are needed at BNL.

Construction of all electronics needed for the Outer HCal assembly has been completed; construction of cables is nearly complete save for one set, the signal cables. These last cables are under construction at the NSLS-II at BNL under COVID protocols for BNL and will arrive ahead of the need-by date.. Testing is complete for the pre-production series of these electronics. Testing is underway but not yet complete for the production series. Multiple sites with multiple students are involved in order to reduce risk from temporary loss of a person or a site due to COVID. The remaining risk is similar to that for shutdown of any other site. We monitor the work regularly and can communicate the testing procedures and setup to other sites if needed or could complete the work at BNL as a potential fall-back solution.

Assembly of the scintillating tiles and electronics into the Outer HCal sectors was suspended for 4 months due to COVID. This work must be done at BNL. The large planned summer effort with students and staff from multiple institutions had to be abandoned due to COVID. Factory space has been set up in Bldg 912 at BNL to pursue it and has been laid out to maintain social distancing. Access to the BNL site for people from local 3-state-area was negotiated a few

months ago and has continued since. Techs on the BNL staff were re-assigned to this work to help re-start it and now to continue it. One new postdoc has been hired by Iowa State U for this work, will be stationed full-time at BNL, and will focus solely on Outer HCal assembly. This will help mitigate delays and inefficiencies due to visitor-testing for other collaborators on the Outer HCal. Five of the 32 sectors have now been instrumented and the next ten sectors placed on the assembly stands to continue the work. Tiles have been placed in these sectors and the addition of readout electronics has begun. If the present pace can be maintained, the work will be complete by February or March, more than 4 months before when the sectors are needed for installation into sPHENIX in 1008. Arrangements are being made to allow other collaborators to join this work to further insure against another COVID inefficiency.

WBS 1.5 Calorimeter Electronics

The order for the SiPMs was completed before the COVID shutdown, as was their testing.

The electronics boards for the pre-production electronics for the EMCal and OuterHCal were completed preCOVID.

The production orders for the electronics boards for the EMCal and OuterHCal electronics were in-progress when the COVID shutdown began, although placement of the orders was partially interrupted by the shutdown – for example, the SiPM daughterboard assembly could only start after the min-safe shutdown was ended and a partial return to work was allowed. Open design issues at the time of the shutdown were resolved, although this did incur some COVID-delay due to the need to make tests in the laboratory. The baseline schedule contained adequate free float such that subsequent installation of these boards on the detectors was not delayed by the electronics delivery schedule. All remaining board orders have been placed. These have been fulfilled save for the production order of EMCal preamplifiers, which is underway at a vendor, who reports no COVID delay issues presently. This was also noted above under the EMCal discussion. Testing of boards remains an area where further delay due to inefficiency is possible, thus this has been organized to not require presence of multiple workers at a given test station. More than one person is familiar with each test to give assurance against loss of key personnel due to illness or mandated quarantine going forward.

The testing of pre-production digitizers was suspended for four months due to the COVID shutdown. This work was resumed at Nevis Laboratory late in the summer and is completed. The production of part of this order of digitizers and ancillary control modules was also suspended at

the vendor due to the COVID shutdown, and this work has since been completed. The P6 baseline schedule for the digitizers provided for some float between pre-production and production orders; this float is now used up. The tests of the pre-production digitizers indicated no hardware or design changes were needed, although some firmware improvements are continuing. Therefore, we proceeded to place the contract for the production quantity of digitizers. The production order for the digitizers was placed in October by BNL with Nevis Laboratory. Nevis in turn is presently contracting with board and parts suppliers for this order. No problematic delays are yet reported by parts suppliers, but the situation continues to be monitored as contracts are placed and parts deliveries are made. The same board vendor and assembly vendor can be used as for the pre-production order, and to date these vendors do not report COVID delays. Nevis plans to kit the parts, procure the bords separately and then send the assembly kits to an assembly house. This allows individual Nevis staff to work separately on the project. More than one Nevis staff member is involved to guard against slowdowns due to one individual's absence. This also provides some protection against loss of a vendor. This effort still preserves over 120 days float. An adequate supply of digitizers is already prepared for use in the calorimeter production testing so that there again is a decoupling of the two schedules.

WBS 1.6 DAQ/Trigger

The COVID shutdown led to a suspension of work on the DAQ procurements, DAQ preproduction prototype computer testing, GL1 and Timing system preproduction prototype testing, and the Local Level 1 Trigger prototype testing. These are discussed in the following.

Since work could resume at BNL the prototype DAQ computers have been tested with the calorimeter electronics readout and separately with the FELIX-based TPC readout. A joint test with both operating together remains in progress. This work has required access to the laboratories at BNL to set up the needed hardware but otherwise can be operated remotely as long as BNL networks remain active and electronics racks are allowed to remain powered on. We note that during the Min-Safe period in March through May, the racks had to be powered off, which forced this work to be suspended; the racks are at the time of this writing allowed to remain powered. A second DAQ expert has been hired into the group, which helps mitigate against loss of key DAQ personnel.

The DAQ hardware testing is complete for the prototype machines. The results show the production machines may be commercial purchases of routinely available hardware. Procurements of the production machines, which include machines used as ATPs, SEBs and buffer boxes, have all moved into contract award stage with the vendors. At present no vendors

expect to encounter delays due to COVID according to vendor responses to date. The needed switch for the DAQ was evaluated and found to need more bandwidth margin, and is being replaced by the vendor to meet the promised specification in the existing purchase contract. The schedule for the DAQ includes presently 6 months for installation, commissioning and software improvements, which should be adequate, given that baseline performance has been demonstrated. Staff working on these machines may do this work largely from home. Multiple staff members are involved to guard against loss of one staff member.

The basic hardware used for the GL1 trigger and the timing system is the same. Testing of both configurations was interrupted by the COVID shutdown and has since resumed. The tests have advanced to the point that production procurements have been made. The needed hardware is a commercial purchase with custom local modifications. Six of the units are in hand and being worked on by two separate (and separated) groups at BNL. The current schedule allows for over 6 months of installation, hardware testing and firmware development after the vendor procurement is complete. This should allow for any further inefficiencies due to another COVID shutdown.

The production and testing of the Local-Level-1 trigger prototype at Nevis had to be suspended due to the COVID shutdown. The board has since been assembled after Nevis could restart laboratory operation and is undergoing testing. Hardware functionality is demonstrated, and coupling to data from the digitizers is under test. To date bit rates and event rates meet specifications. Further firmware development is a joint effort between Nevis Laboratory and U Colorado and does require the system to be functioning in a laboratory but otherwise can be pursued remotely. This work is still planned to have a preproduction prototype phase after the current testing terminates, followed by a production in quantity of the pre-production board design. To date testing reveals no need to change the board layout or parts selection. If this continues to hold, the fabrication of a pre-production prototype can be skipped and the effort can move directly to production, saving several months in the schedule. This time would in turn become further buffer against COVID-related inefficiencies. Any board design changes can be made while working remotely, as has been the case for the other sPHENIX electronics development efforts, but testing of new board designs does require access to the laboratory at Nevis, which remains a risk due to COVID. Parts suppliers do not indicate at present any untimely delays in parts deliveries, but this will have to be monitored going forward. Presently there are 3 months float remaining in the schedule for the Local Level-1 trigger boards. This would increase if the preproduction prototype step is not needed, but this is not yet known.

WBS 1.7 MinBias Trigger Detector (MBD)

The detectors for the MBD were readied before the COVID shutdown.

Testing of the preproduction shaper/discriminator board was suspended due to COVID. During this period a design change to improve the timing resolution was identified and implemented. Once Nevis Laboratory was allowed to resume work, this design change was tested and shown to meet all specifications. Testing is still underway but is performed all by personnel inside the New York State region, thus no COVID-directed quarantines for out-of-region personnel are required.

A contract for the production MBD discriminator/shaper boards remains to be placed by BNL with Nevis Laboratory. No issues are anticipated with this, because the much larger contract for the digitizers was just placed. The actual production requires returning to the same vendors as produced the prototype boards, who do now not report COVID delays.

The digitizers needed for the MBD are part of the larger order for the calorimeters, noted above under WBS 1.5

2) **Conduct a comprehensive EAC update taking into account future COVID impacts due to social distancing inefficiencies.**

The sPHENIX Project team worked with the sPHENIX L2 Managers to update the EAC taking into account anticipated COVID impacts due to social distancing inefficiencies and any other issue that required a revision of the EAC. The collected information and its impact on the EAC resulted in Project Change Request -17 (PCR-17) which was approved by the sPHENIX Change Control Board. The EAC for the sPHENIX MIE after performing this exercise was **24.31 M AY$**. The sPHENIX MIE ETC as of November 2020 is **10.3 M AY$**. The sPHENIX Total Project Cost is **$27.0 M**.

A detailed description of the changes to the EAC are as follows:
TPC Module technical support - reduction of schedule risk due to loss of student labor at Stony Brook post-COVID. This is addressed by hiring technician help for module assembly effort. TPC Assembly technical support - reduction of schedule risk due to loss of student labor at Stony Brook post-COVID. This is addressed by hiring technician help for TPC assembly effort. Risk sPH_TPC_010 ($30K EVM) will be realized. TPC Front-End Electronics - reduction of technical risk for the TPC from end electronics by adding diode-protection networks, substituting radiation-hard components in key places as determined by radiation-qualification tests of the components for the front-end electronics, and reduction of risk from loss of command-and-control of the electronics due to radiation-induced upset events by adding a separate download path for control programs and needed timing signals. TPC Diffuse Lasers - reduction of risk due to electric-field distortion, resulting from time-varying charge-build-up in the TPC during operation, and the resultant worsening of the resolution of the TPC and loss of resolution of the sPHENIX tracking system. This is addressed by adding a system of diffuse-light lasers that illuminate specific locations on the TPC central membrane, causing emission of electrons at known time and space points which can then be tracked through the TPC volume and used as a real-time calibration and correction of the above distortions, thus recovering the TPC tracking resolution. Risk sPH_TPC_012 ($140K EVM) will be

realized. EMCal Block production QA - reduction of risk to EMCal block performance and shape by addition of specific manufacturing steps and quality control procedures, plus reduction of EMCal block production schedule risk at Illinois post-COVID. This is addressed by obtaining needed equipment and hiring addition technician help to execute these steps which improve EMCal block light yield and dimension control in particular, and hiring added technician help to speed certain key manufacturing steps. Risk sPH_EMCal_007 ($300K EVM) will be realized. Manufacture Inner HCal Support Rings - reduce technical and schedule risk for the inner HCal support rings by adding all needed design features for these rings. This is addressed by revising the design features for these rings to their detailed manufacturing drawings. Trunk Signal Cables - EMCal - reduce cost and schedule risk for the trunk signal cables for the EMCal. This is addressed by revising the lengths to match required routing of these cables on the sPHENIX platforms and by selecting a cable type that preserves the required signal quality as the signals travel from the preamplifiers and interface cards, on the detector itself, over to the high-speed flash-digitizing electronics located in crates on the detector platforms. Trunk Signal Cables – Outer HCal - reduce cost and schedule risk for the trunk signal cables for the Outer HCal. This is addressed by revising the lengths to match required routing of these cables on the sPHENIX platforms and by selecting a cable type that preserves the required signal quality as the signals travel from the preamplifiers and interface cards, on the detector itself, over to the high-speed flash-digitizing electronics located in crates on the detector platforms. Risk sPH_CalEl_014 ($800K EVM) will be realized. Total $1,270K risks will be realized when this PCR017 is approved.

Table 1: The revised EAC by fiscal year with burdened and escalated numbers as of November 30, 2020.

	Start	Finish	Burdened AY$	FY17	FY18	FY19	FY20	FY21	FY22	WBS	FY21 Delta	FY22 Delta
Project: POM02B-PCR017 POM02 sPHENIX WBS 1.x, 2.x Baseline PCR017	01-Feb-17 A	15-Oct-21	24,309,836	210,190	1,816,761	4,609,334	6,724,462	10,935,716	13,373			
WBS: POM02B-PCR017.1 MIE Project	01-Feb-17 A	15-Oct-21	24,309,836	210,190	1,816,761	4,609,334	6,724,462	10,935,716	13,373			
WBS: POM02B-PCR017.1.01 Project Management	01-Feb-17 A	14-Oct-21	1,951,679	107,107	893,953	488,827	272,957	177,474	11,361		$ -	$ -
WBS: POM02B-PCR017.1.02 TPC	01-Feb-17 A	15-Oct-21	4,702,483	20,961	274,664	811,579	1,304,292	2,288,981	2,005	1.02	$ 520,343	$ 2,005
WBS: POM02B-PCR017.1.03 EMCal	01-Feb-17 A	8-Oct-21	5,789,008	45,714	463,282	1,347,886	2,110,455	1,821,664	8	1.03	$ 533,915	$ -
WBS: POM02B-PCR017.1.04 HCal	01-Feb-17 A	10-Sep-21	4,160,785	3,021	142,473	685,258	1,655,863	1,674,170		1.04	$ 127,676	$ -
WBS: POM02B-PCR017.1.05 Calorimeter Electronics	01-Feb-17 A	30-Jul-21	6,290,621	33,387	39,193	1,153,860	1,164,852	3,899,329		1.05	$ 927,154	$ -
WBS: POM02B-PCR017.1.06 DAQ/Trigger	02-Oct-17 A	29-Jun-21	1,245,090		2,782	23,191	216,042	1,003,076		1.06	$ -	$ -
WBS: POM02B-PCR017.1.07 Min Bias Trigger Detector	01-Oct-17 A	22-Feb-21	170,170		414	98,734		71,022		1.07	$ -	$ -
Project: POM02B POM02 sPHENIX WBS 1.x, 2.x Baseline PCR016	01-Feb-17 A	14-Oct-21	22,198,743	210,190	1,816,761	4,609,334	6,724,462	8,826,628	11,369	Delta by FY	$ 2,109,088	$ 2,005
WBS: POM02B.1 MIE Project	01-Feb-17 A	14-Oct-21	22,198,743	210,190	1,816,761	4,609,334	6,724,462	8,826,628	11,369		Total Delta	
WBS: POM02B.1.01 Project Management	01-Feb-17 A	14-Oct-21	1,951,679	107,107	893,953	488,827	272,957	177,474	11,361		$ 2,111,093	
WBS: POM02B.1.02 TPC	01-Feb-17 A	15-Apr-21	4,180,135	20,961	274,664	811,579	1,304,292	1,768,638				
WBS: POM02B.1.03 EMCal	01-Feb-17 A	8-Oct-21	5,255,093	45,714	463,282	1,347,886	2,110,455	1,287,749	8			
WBS: POM02B.1.04 HCal	01-Feb-17 A	10-Sep-21	4,033,110	3,021	142,473	685,258	1,655,863	1,546,494				
WBS: POM02B.1.05 Calorimeter Electronics	01-Feb-17 A	7-May-21	5,363,466	33,387	39,193	1,153,860	1,164,852	2,972,175				
WBS: POM02B.1.06 DAQ/Trigger	02-Oct-17 A	29-Jun-21	1,245,090		2,782	23,191	216,042	1,003,076				
WBS: POM02B.1.07 Min Bias Trigger Detector	01-Oct-17 A	22-Feb-21	170,170		414	98,734		71,022				
FY Delta				0	0	0	0	2,109,088	2,004			

Table 2. The individual contributions by sPHENIX L2 subsystems to PCR-17 and its impact on the EAC

PCR for MIE Allocation of Known Risk Elements
October 24 2020

System	Area	Issue	Additional Cost	Proposed Activity ID	Proposed Start	Proposed Finish	
TPC	Diffuse Lasers	Number and power unknown prior to ongoing optical design definition and component selection	$200,000	S149650	12/1/2020	4/30/2021	
TPC	Module technical Support	Unavailability of students due to COVID	$80,000	S113050	12/1/2020	4/30/2021	
	TPC Assembly technical Support	Unavailability of students due to COVID	$20,000	S121950	5/1/2021	11/30/2021	
TPC	Front End Electronics	Phase 3 delivery - Diode Protection Network	$150,000	S143250	12/1/2020	5/28/2021	
EMCal	Block Production	Tech Effort for Required additional QA steps	$460,000	S172870	12/1/2020	12/31/2021	
HCal	Inner HCal End Rings	Cost estimate	$110,000	S200000	12/1/2020	5/12/2021	revision of existing activity
Calorimeter FEE	Trunk Signal Cables - EMCal	Cost estimate, type, actual length	$670,160	S233250	12/1/2020	7/31/2021	
	Trunk Signal Cables - OuterHCal	Cost estimate, type, actual length	$128,640	S244450	12/1/2020	7/31/2021	
		TOTAL PCR Amount (Direct)	$1,818,800				
		TOTAL Risk realized	$1,270,000				
		Effective contingency reduction	$548,800				

Figure 1: Cost Performance Report for November 2020

CA (3)	CUMULATIVE TO DATE					AT COMPLETION				
	BUDGETED COST		ACTUAL	VARIANCE		BUDGETED	ESTIMATED	VARIANCE		
ITEM	WORK SCHEDULED	WORK PERFORMED	COST WORK PERFORMED	SCHEDULE	COST					
(1)	(7)	(8)	(9)	(10)	(11)	(14)	(15)	(16)	SPI	CPI
1.01A Project Management	1,790,636	1,790,636	1,641,468	0	149,168	1,951,679	1,802,510	149,168	1.00	1.09
1.02A TPC	2,646,885	2,358,027	2,135,898	-288,857	222,129	4,702,483	4,488,768	213,715	0.89	1.10
1.03A EMCal	4,244,457	4,070,513	4,271,654	-173,944	-201,141	5,789,008	5,994,849	-205,841	0.96	0.95
1.04A HCal	2,813,010	2,513,268	2,489,745	-299,742	23,523	4,160,785	4,143,384	17,401	0.89	1.01
1.05A Calorimeter Electronics	3,079,336	2,661,930	2,702,840	-417,406	-40,910	6,290,621	6,332,844	-42,223	0.86	0.98
1.06A DAQ & Trigger	242,014	525,778	564,510	283,764	-38,732	1,245,090	1,286,922	-41,831	2.17	0.93
1.07A MinBias Trigger Detector	99,148	99,148	78,926	0	20,221	170,170	149,948	20,221	1.00	1.26
b. COST OF MONEY	0	0	0	0	0	0	0	0		
c. GENERAL AND ADMINISTRATIVE	0	0	0	0	0	0	0	0		
d. UNDISTRIBUTED BUDGET						0	0	0		
e. SUBTOTAL	14,915,485	14,019,300	13,885,041	-896,185	134,259	24,309,836	24,199,225	110,611	0.94	1.01
f. Contingency						2,690,164				
g. TOTAL	14,915,485	14,019,300	13,885,041	-896,185	134,259	27,000,000				
9. RECONCILIATION TO CONTRACT BUDGET BASELINE										
a. VARIANCE ADJUSTMENT				0	0					
b. TOTAL CONTRACT VARIANCE				-896,185	134,259	0	0	0		

CLASSIFICATION (When Filled In)

$10,314,184	ETC
$10,290,535	BCWR
26.08%	% Contingency on ETC
26.14%	% Contingency on Remaining Work
61.36%	% Planned
57.67%	% Complete
57.12%	% Spent

DOE SPI or CPI Value Thresholds
- 0.90 to 1.15
- 0.85 to 0.89 or 1.16 to 1.25
- <0.85 or >1.25

*Highlights in table above takes variance $ into consideration, not just Indices

3) By the end of FY20, revisit the Risk Register to review the assigned likelihoods and impacts and to check the consistency of assumptions across the project.

We update the Risk Registry whenever a risk is modified, retired, or a new risk is identified. This process typically takes place after discussions at the monthly sPHENIX L2 Managers' meeting. After the 2020 Annual Review we reexamined the risks in the Risk Registry based on comments and recommendations

in the Annual review committee report and also in response to comments from the review committee made during the review presentations. The November 2020 Risk Registry is shown in Table 3.

Table 3: Revised Risk Registry for November 2020.

Risk ID Number	RLS activity	Risk Owner	Risk Name	Overall Impact Score (Residual)	Risk Likelihood (%)	Sched. Impact	Low Cost Impact ($K)	Likely Cost Impact ($K)	High Cost Impact ($K)	Low Schedule Impact (Mo)	Likely Schedule Impact (Mo)	High Schedule Impact (Mo)	EVM
Mgmt_001	101022	Ed O'Brien	Departure of Key Personnel	Moderate	10%	Moderate	0	0	0	1.0	3.0	6.0	0
Mgmt_002	101022	Ed O'Brien	Safety incident	Low	2%	Low	0	0	0	0.1	0.5	1.0	0
Mgmt_003	101015	Ed O'Brien	Funding profile stretches	High	20%	Low	0	50	100	0	3	6	10
Mgmt_008	101022	Ed O'Brien	COVID-19 delays	High	50%	Moderate	200	300	400	4.0	6.0	8.0	150
sPH_TPC_002	120200	Tom Hemmick	Success of v1 field cage prototype	Low	50%	Negligible	-150	-150	-150	-4.0	-4.0	-4.0	-75
sPH_TPC_007	149600	Tom Hemmick	Vanderbilt Students Unavailable (R2 Modules)	Low	10%	Low	0	0	120	3.0	4.0	6.0	0
sPH_TPC_008	112100	Tom Hemmick	Temple Students Unavailable (R3a Modules)	Low	10%	Low	0	0	120	3.0	4.0	6.0	0
sPH_TPC_009	129500	Tom Hemmick	Weizmann Students Unavailable (R3b Modules)	Low	10%	Low	0	0	120	3.0	4.0	6.0	0
sPH_TPC_010	133700	Tom Hemmick	SUNY Stony Brook Staff and/or Students Not Available (TPC)	High	5%	Moderate	40	60	80	3.0	6.0	8.0	3
sPH_TPC_011	134000	Tom Hemmick	Delay of GEM production	High	20%	Moderate	0	0	0	2	3	6	0
sPH_TPC_012	112900	Tom Hemmick	Insufficient laser power for diffuse illumination	High	5%		140	140	140	0	0	0	7
sPH_EMCal_004	178100	Craig Woody	Delay of EMCal block production at UIUC due to component supplies or technical	Low	10%	Low	0	0	0	0.2	0.5	1.0	0
sPH_EMCal_005	196500	Craig Woody	Delay of EMCal module production or sector assembly rate due to component	Low	20%	Low	0	0	0	0.2	0.5	1.0	0
sPH_EMCal_007	178100	Craig Woody	Labor and M&S estimates low and more of each is needed to stay on schedule	High	0%	Low	300	300	300	0.3	0.5	1.5	0
sPH_EMCal_009	172800	Craig Woody	UIUC students not available for EMCal Fiber Assemblies	Moderate	10%	Moderate	0	100	0	3	6	6	10
sPH_EMCal_010	178100	Craig Woody	UIUC students not available for EMCal Final Block Fabrication	Moderate	20%	Moderate	0	0	0	3	6	6	0
sPH_EMCal_011	196500	Craig Woody	Loss of Students for Sector testing	High	40%	Moderate	0	0	200	1	3	6	0
sPH_HCal_001	208312	John Lajoie	Loss of scintillating tile provider (Uniplast)	High	10%	Moderate	0	160	160	6.0	12.0	12.0	16
sPH_HCal_003	208400	John Lajoie	Georgia State U Staff and/or Students Not Available for HCal scin. tiles testing	High	50%	Low	0	0	72	1.0	2.0	2.0	0
sPH_HCal_004	209800	John Lajoie	Georgia State U Staff and/or Students Not Available for HCal sector assembly and	High	50%	Low	0	0	648	0.0	2.0	4.0	0
sPH_CalEl_009	229300	Eric Mannel	EMCal electronics components procurement is late (preamps)	Low	25%	Low	0	0	0	1.0	3.0	6.0	0
sPH_CalEl_011	240600	Eric Mannel	EMCal electronics components procurement is late	Low	10%	Low	0	0	0	1.0	3.0	6.0	0
sPH_CalEl_012	252900	Eric Mannel	Digitizer component prices go up	Moderate	70%		94	94	94	0.0	0.0	0.0	65.8
sPH_CalEl_013	252700	Eric Mannel	Digitizer components procurement is late	Moderate	10%	Moderate	0	0	0	1.0	3.0	6.0	0
sPH_CalEl_014	233200	Eric Mannel	EMCal, Hcal signal/power cables cost more	High	0%	Moderate	800	800	800	1.0	3.0	6.0	0
sPH_DAQ&Tr_005	255000	Martin Purschke	TPC produces higher data rate than we can store	Low	30%		50	100	150	0.0	1.0	2.0	30
sPH_DAQ&Tr_001	258900	Martin Purschke	DAQ Prototype does not meet specifications	Low	5%		10	35	74	0.0	0.0	0.0	1.75
MinBias_001	272600	Mickey Chiu	Failure of D/S Board Prototype	Low	10%	Negligible	0	0	0	0.0	2.0	3.0	0
MinBias_002	273600	Mickey Chiu	Nevis Labor not available	High	50%	Negligible	35	70	105	1.0	3.0	6.0	35

The bottom up contingency calculation containing for the residual risk and the estimate uncertainty on the remaining work is shown in Table 4. The total bottom up contingency is $1.362 M. The available contingency as of November 2020 is $2.690M as shown in the Cost Performance Report in figure 1. Note that the one risk opportunity in the Risk Registry has not been included in the bottom-up total.

Table 4: Bottom Up contingency estimate for November 2020.

	EU $ FY21	EU $ FY22	Total EU	Risk EMV	Total Bottom Up Contingency
1.01A	$8,874	$568	$9,442	$160,000	$169,442
1.02A	$362,600	$3,496	$366,096	$10,000	$376,096
1.03A	$109,262	$53	$109,315	$10,000	$119,315
1.04A	$137,048	$0	$137,048	$16,000	$153,048
1.05A	$270,341	$0	$270,341	$66,000	$336,341
1.06A	$123,081	$0	$123,081	$32,000	$155,081
1.07A	$17,756	$0	$17,756	$35,000	$52,756
Grand Total	**$1,028,961**	**$4,117**	**$1,033,078**	**$329,000**	**$1,362,078**

4) **Prepare a plan by the end of October 2020, with anticipated decision dates, for potential scope opportunities that could be implemented should the project continue to perform well.**

Table of potential project scope opportunities for the sPHENIX MIE.

Additional scope items	Estimated burdened cost
Additional FELIX boards	$300k
Additional TPC Fee boards	$200k
Additional Rack of EDBC/SEB computers	$200k
Additional ADC and XMIT boards	$300k
Additional LL1 Trigger Boards	$200k
Additional Disk arrays	$200k
Additional Rack and Slow Controls equipment	$200k
Additional LVPS	$150k
Additional TPC Calibration equipment	$500k
Total	**$2250k**