sPHENIX Project Status Report – March 2021

HOST LABORATORY: BROOKHAVEN NATIONAL LABORATORY

FEDERAL PROGRAM MANAGER: ELIZABETH BARTOSZ

BHSO POINT OF CONTACT: ROBERT CARADONNA

CONTRACTOR PROJECT DIRECTOR: EDWARD O'BRIEN

1. **SCORECARD AS OF March 31, 2021**

Current PD:	**2/3**	Date of Current CD/PD approval		September 2019	
Next PD:	**4**	Forecast approval:	**1QFY23**	Baseline:	**1QFY23**
% Complete:	**68.2%**	Planned:		**84.6%**	
ETC:	**$7.82M**	TPC or Cost Range:		**$27.0M**	
Contingency:	**27.4%** on ETC	Float to PD-4 in months:		**10.75**	
Cumulative CPI:	**1.01**	Cumulative SPI:		**0.81**	

2. **NEAR TERM MILESTONES**

The sPHENIX Project team will continue the monthly EVMS process, Change Control, and updating of the ETC. We will continue to place orders for detector components approved at PD-3. We will also continue to implement the plan to mitigate COVID-19 related delays and have hired additional technical and engineering labor at both BNL and universities to maintain the project schedule. We expect that the schedule delays that we have experienced during the US COVID peak from November 2020 to 2021 will reduce from March forward. There was no change in the early completion date in March. We expect the SPI to slowly improve over the next few months as the US COVID cases continue to diminish and vendors deliver on components that had previously been delayed. We will continue to hold Final Design Reviews and Production Readiness Reviews for any MIE components remaining to be ordered.

The TPC Al stripes will be evaporated onto the central membrane petals. The TPC Inner and Outer field cage pieces will begin assembly into the final full unit. Full production FEE will be ordered pending a successful completion of TPC preproduction board testing. Reviews of the laser system (design and safety) will occur in the coming months.

Production of blocks for Sectors 13-64 will continue at UIUC. The current rate of block production is close to the level of 66 blocks per week required to complete all of the blocks by the end of CY 2021. The addition of a new machinist at UIUC should enable us to reach and maintain the required block production rate. Module production and sector assembly will continue at BNL. There are currently sufficient EMCal sector components to complete up to Sector 19 with the exception of EMCal preamps. However, we expect that more preamps will arrive in early April (editors note: the preamps have arrived at BNL), which will allow us to complete additional sectors and to stay on schedule.

ISU and Rutgers will continue to coordinate with the vendor fabbing the IHCal sectors to ensure good communication and adherence to the production schedule. IHCal sector assembly will begin in earnest in the mid- to late-July time frame, driven by the availability of components. Over the next several weeks, work will continue in the oHCAL factory to burn-in the oHCAL sectors prior to Installation on the sPHENIX carriage starting in early June.

Work over the next 3 months will be focused on the continued testing of assembled EMCal and HCal sectors and design and construction of racks for on-detector electronics. This work includes the completion of EMCal SiPM board and preamp testing, completion of the HCal power/burn-in rack, completion of the first calorimeter digitizer rack with a fully operational crate, placement of the calorimeter cable orders, production of the LV distribution system, beginning of the assembly of the digitizer system and rack assembly.

The delivery of more computer racks for the DAQ/Trigger system is expected in a few weeks. After arrival, the computer racks will be installed, the hardware set-up followed by the set-up of the networks and installation of the operating system on the PCs. Concurrently, we will work on the preparations for the slice test, and finalize the engineering for the "hot box".

Work on the MBD D/S chain test is ongoing with completion planned for the end of June. BNL personnel continue to meet weekly with grad students from Howard and Florida A&M Univ to train them on the MBD and the skill set required for testing and eventually for operating the MBD. Columbia Univ, Nevis Labs personnel will continue to oversee the procurement of the production MBD electronics.

3. **STATUS HIGHLIGHTS**

Production components for the sPHENIX detector continue to arrive. Recent project activities are primarily associated with production and assembly of final detector components. The early completion date for sPHENIX did not change in March. Ten months and three weeks of schedule contingency to the PD-4 date remains. The project cost performance remains excellent. EVMS processing was completed for March. Cobra and P6 monthly reports uploaded to IPD. The variance reports were approved. A Final Design Review of the Local Level 1 Trigger electronics was completed in March, as was the Procurement Readiness Review for the TPC Line Laser. The project is 68.2% complete in February with a 27.4% contingency on the ETC. The project is 84.7% costed and committed.

The TPC R1 pad planes arrived and 100% of them passed microscope inspection. These are the highest quality boards yet received. The delivery of all TPC pad planes, R1, R2 and R3 is now complete. Initial TPC cooling block parts arrived and were fitted to the actual wagon wheel successfully. Significant progress is made toward the TPC Fee slice test as all parts are in hand and have been successfully assembled. The assembly of all "in-hand" parts of the TPC assembly cart is complete. Masks for the TPC central membrane have arrived and passed inspection.

Over 44% of the EMCal blocks have been completed at UIUC as of 3/25 (editors note: we have surpassed 50% as of mid-April). All but the final 17% of the sPHENIX EMCal blocks are in various stages of production. The UIUC block rate reached ~ 60 blocks per week for the past several weeks. To meet the early completion date the block production must average 66 blocks/week. A new machinist has been hired by UIUC and will start April 7th, which should enable UIUC to increase and maintain the production rate. Work on module production and sector assembly continued at BNL. All of the modules for Sectors 1-20 have been completed and the modules for

Sectors 21 are ready to be glued. Sectors 16-19 have been assembled at BNL and await preamp installation. A shipment of 96 high eta EMCal blocks arrived at BNL from Fudan University on March 31. The high eta block production is on schedule.

The assembly of the final OHCal sector was completed March 26. The full shipment of high-strength endplates, splice plates, and pucks and pins for oHCAL assembly have all passed BNL QA inspection and are available for oHCAL installation later starting in early June. ISU has contracted with a vendor to build the iHCal sectors. The delivery schedule has been coordinated with Rutgers to ensure that the parts provided will arrive well in advance of when they are needed for assembly. The Rutgers shops have completed all the IHCal absorber end plates. The delivery of the first eight IHCal sectors to BNL is scheduled for late May, early June 2021. The iHCal end rings have been received by BNL. Work is also underway to complete analysis of the cosmic ray and LED data and prepare the initial calibration constants for the sPHENIX offline database.

All electronics and cables needed to assemble the OHCal have been delivered to the HCal group. Delivery of the production orders for the EMCal SiPM daughterboards and preamps from the assembly house continues. Preamp and SiPM board delivery is expected to be complete in April 2021. Testing of both the EMCal SiPM daughterboards and preamps continues with a high yield rate. The final delivery of all the bias supplies for the EMCal and HCal was received in March. The vendor for the Calorimeter electronics LV bulk supplies has started to ship the power supplies to BNL. The requisition for the EMCal and HCal external signal cables was submitted at the end of March 2021. The Columbia University purchasing department has started to issue purchase orders for components needed for the production of the digitizer electronics. Parts deliveries are scheduled to start over the next 3 months. The University of Colorado group continues to refine the testing and documentation process for the digitizer boards.

The DAQ/Trigger group has been working with the engineers from the Collider-Accelerator Department to plan the support, power, and cooling needs for the DAQ machines that are already partially installed. A number of add-on prototype cards for the Global Level 1 and Global Timing Module have been received back from the assembly house and are being tested. Preparation for the TPC slice test, a system test of 26 TPC Fee board, continues.

We are assembling the test-stand for the chain-test of the prototype MBD electronics with the BBC detector here at BNL. BNL and Columbia University scientists have started regular meetings on developing the MBD LL1 trigger and plans for its testing. Columbia University, Nevis Labs has completed the contract for purchasing the final MBD production electronics.

An FDR was held for the MBD electronics on Feb. 8. The only major comment from the review was that we should do a full chain test with the BBC, actual cables we will use to send the signals, and the new electronics. An anomalous timing result from an earlier bench test of the prototype MBD electronics has been resolved. We achieved a 30-40 ps timing resolution in all tests.

WBS 1.1 Project Management (L2 Manager: Irina Sourikova)

Current Status

- SPI is 0.81, CPI is 1.01.

Highlights:

- Local Level 1 Electronics Final Design Review complete.
- TPC Line Laser Procurement Readiness Review complete.
- EVMS processing complete.
- Cobra and P6 monthly reports uploaded to IPD.
- Variance reports approved.

Plans for the next 2-3 months:

- Continue monthly EVMS process and Change Control.
- Implement corrective actions to improve schedule performance.

Issues:

- No issues

WBS 1.2 Time Projection Chamber (L2 Manager: Tom Hemmick, SBU)

Current Status:

GEM foils from the fifth major shipment from CERN arrived on time. The R1 pad plane arrived and 100% passed microscope inspection (highest quality boards yet received). This completes the delivery of all pad planes for the TPC project.

Initial cooling block parts arrived and were fitted to the actual wagon wheel successfully. They were additionally installed onto the 3D printed model of one section. The fit of parts into the 3D printed model was successful but tight, possibly due to imperfections in the 3D printed model. The tight fit was investigated and determined not to be a concern as fitting into the real machined aluminum wagon wheel is the actual requirement.

Test samples of the new motors used for the steering of the line laser were ordered and will be delivered for final evaluation in April. Studies of the light loss in the quartz bar were completed and shown to be satisfactory. Negotiations for production of the quartz bars are under way with two capable manufacturers.

Significant progress is made toward the slice test as all parts are in hand and mechanically fitted together successfully.

The assembly of all “in-hand” parts of the TPC assembly cart is finished. The central shaft (9.960” stainless tube) was successfully made by an outside company after the BNL central shops reported their inability to deliver the piece on time. A second piece of the assembly cart (the so-called “pocket”) has additionally been identified as a part that cannot be made expeditiously at BNL central shops. That job has been farmed out from the SBU shops to the same firm that made the TPC strongbacks and is expected with a 4-5 week delivery. This is not yet a schedule driver because of the reasonable price and delivery schedule of the outside small business that will deliver the parts.

A new and simpler support for the TPC as been designed that eliminates concern about thermal expansion without the use of kinematic mounts, thereby holding the TPC more securely.

Masks for the central membrane have arrived and passed inspection.

Work Anticipated 2-3 Months:

The Al stripes will be evaporated onto the central membrane petals. The field cage pieces will begin assembly into the final full unit. Full production FEE will be ordered pending a successful test of preproduction round electronics. Reviews of the laser system (design and safety) will occur in the coming months.

Issues:

The miscommunication with BNL central shops that lead to the identification of the "pocket" parts being late has slowed the TPC assembly cart progress, but not shifted the overall schedule since this still has some float remaining.

COVID-related Issues:

The Temple factory was idled for two weeks due to COVID positive workers. Because past performance of Temple has shown a capability above the baseline assumptions, we expect that the timeline will be restored in April or May at the latest.

As the sixth and seventh GEM foil batches are due from CERN in late April/early May, we are still concerned whether there would be a shutdown of the CERN GEM shop. A COVID stand down in Lund has halted the SAMPA chip testing and a mitigation strategy will need to be devised in April.

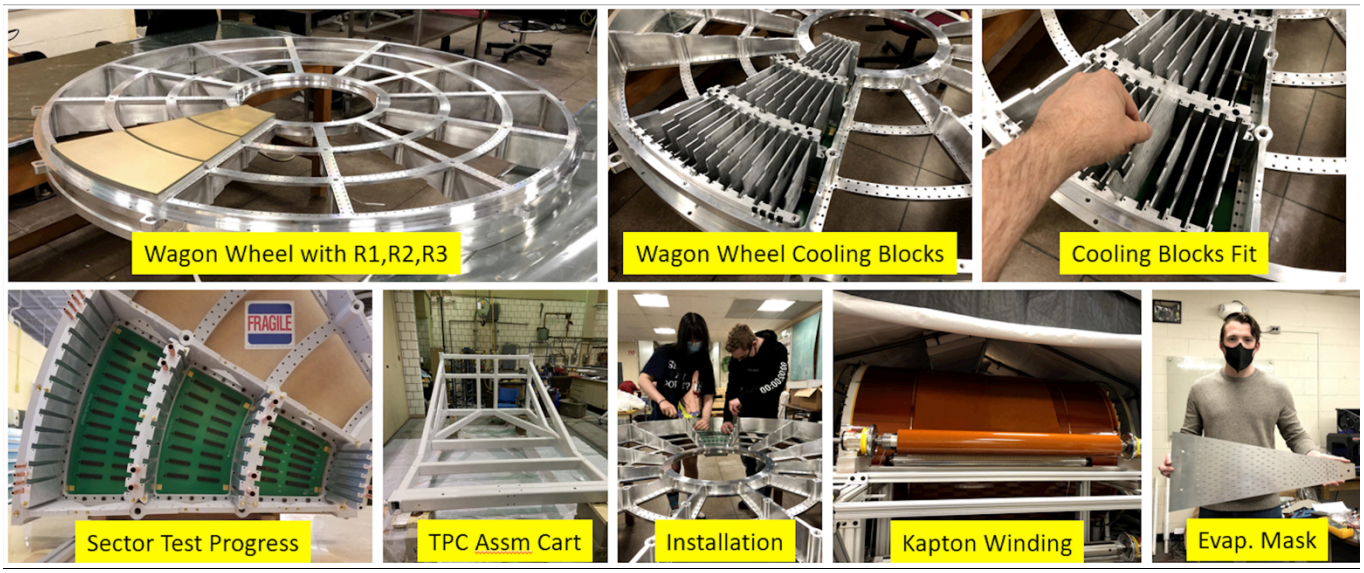


Figure 1: Clockwise from upper left: The TPC Wagon Wheel with R1, R2, R3 pad planes installed; Wagon Wheel with cooling blocks for the TPC Fee boards installed; cooling block fit-up; evaporator mask for the TPC central membrane; kapton winding for the outer field cage; test installation of pad planes into Wagon Wheel; TPC assembly cart; preparation for the TPC Fee slice test.

WBS 1.3 Electromagnetic Calorimeter (L2 Manager: Craig Woody, BNL)

Current Status:

Figure 2 shows the overall status of EMCal block production at UIUC as of March 25th. It shows the number of completed blocks, the number that have been shipped to BNL, the number of Sector 13-64 blocks to be started, the number of fiber sets completed and available for assembly, and other blocks at various stages of production. The rate of rejected blocks was 2.4%.

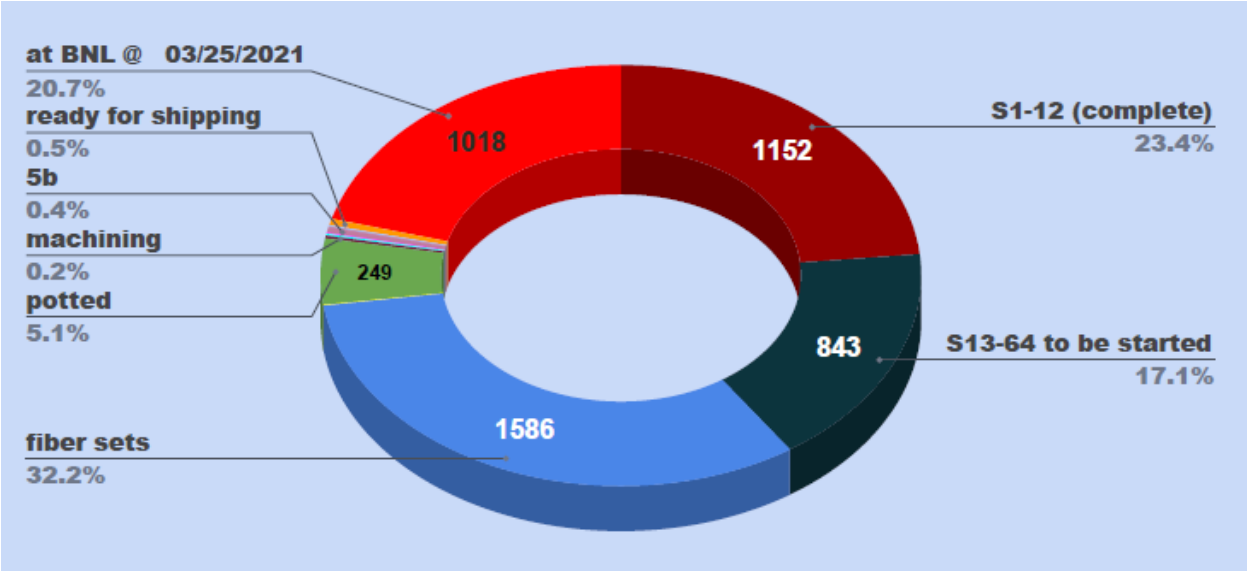


Figure 2. Status of block production at UIUC as of March 25.

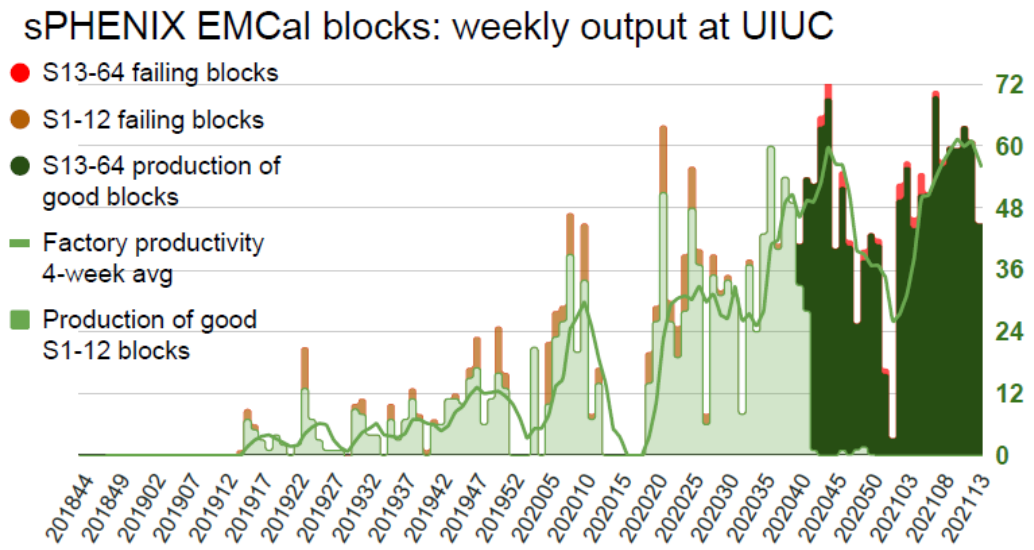


Figure 3. Weekly rate of block production at UIUC (moving average over 4 weeks; note that the last bin does not include 4 full weeks).

Figure 3 shows the weekly rate of block production at UIUC. The rate reached ~ 60 blocks per week for the past several weeks. In order to complete the production of all the remaining blocks by the end of 2021, we need to achieve an average rate of 66 blocks per week. A new machinist has been hired and will start working on April 7 which should greatly help to increase and maintain the production rate.

Block production resumed at a higher rate at Fudan after the Chinese New Year holiday. The goal is to reach at least 24 blocks per week. As shown in Fig. 4, more than 150 blocks have been machined and tested. All blocks passed QA tests and 96 blocks were sent to BNL at the end of March. The high eta block production remains on schedule.

Figure 4. Machined blocks at Fudan before shipment to BNL.

Work on module production and sector assembly continued at BNL. Figure 5 shows the status of the various stages of module production as of March 26th. All of the modules for Sectors 1-20 have been completed and the modules for Sectors 21 are ready to be glued. The optical epoxy we have been using for the light guides and reflector plates (Bicron BC-600) was discontinued but the vendor provided an exact replacement from Loctite which we are testing for optical quality and mechanical strength. We currently have enough light guides to complete modules for up to Sector 26 and expect to continue receiving them on a regular basis. The shipment of 96 blocks from Fudan arrived at BNL on March 31 and should be delivered to the Physics Department within the first few days of April.

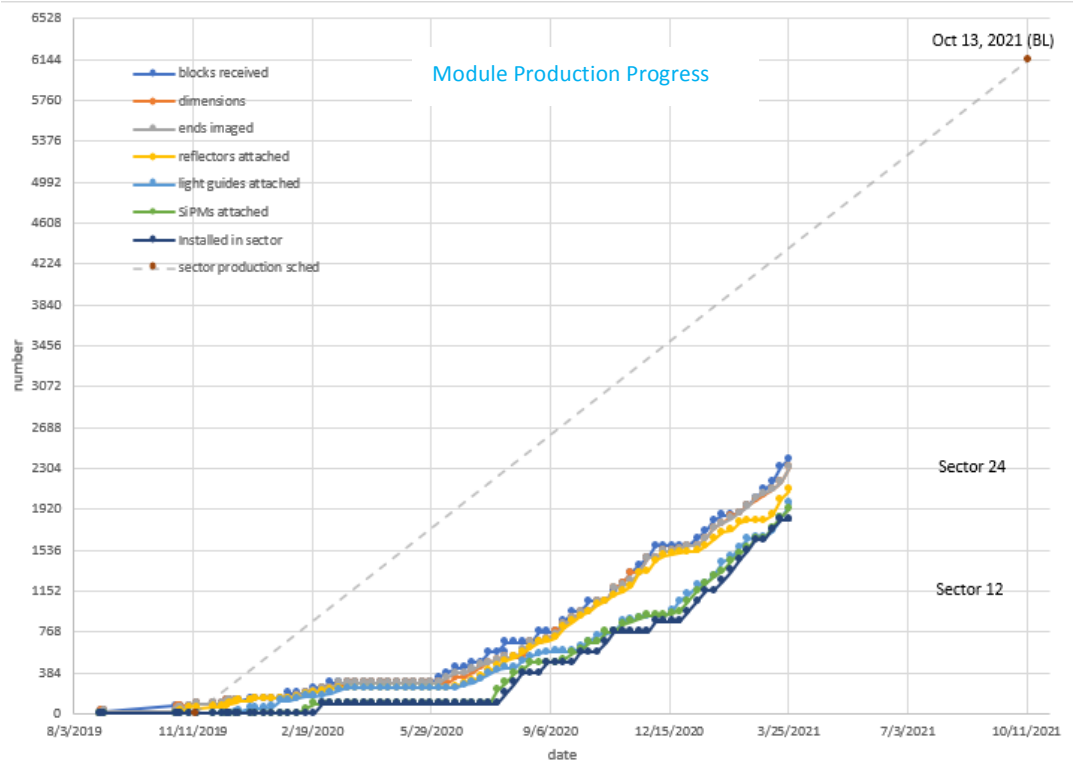


Figure 5. Status of module production at BNL as of March. 26th.

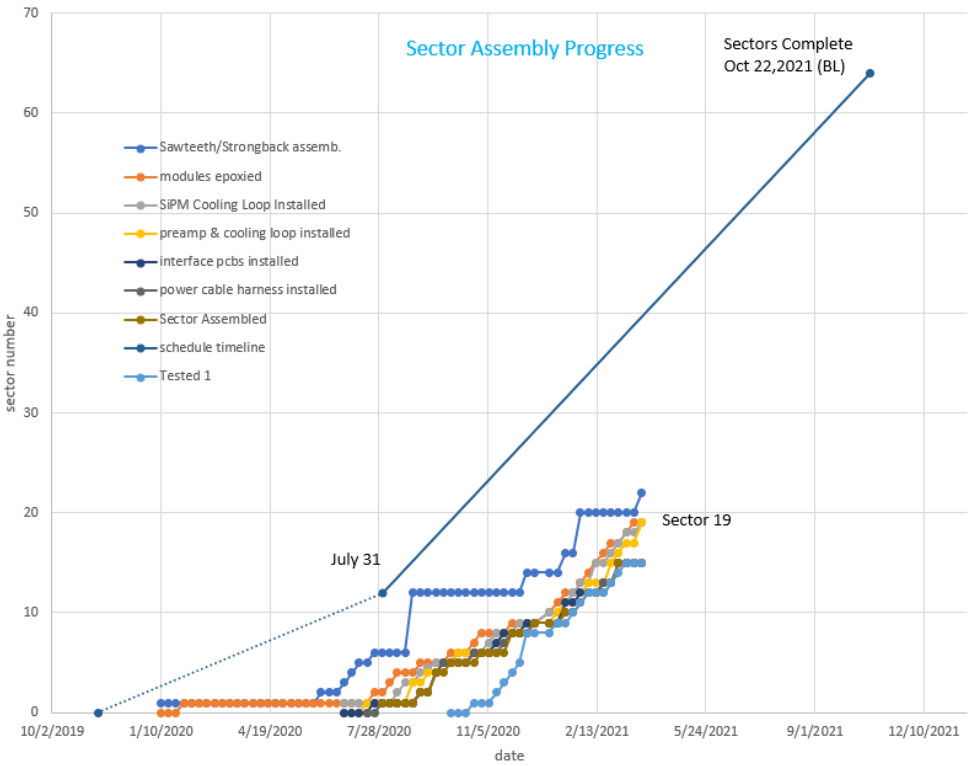


Figure 6. Status of sector assembly at BNL as of March 26.

Figure 6 shows the status of sector assembly. Fourteen sectors have been completed and tested and sector 15 is under test. Sectors 16-19 have been assembled up to the point of installing the preamps, as of March 26 we do not have enough preamps to proceed with the completion of these sectors. However, we are expecting more preamps to arrive within the next week which would allow these sectors to be completed. We now have enough cooling loops for up to Sector 28 and enough assembled sawteeth and strongbacks for up to Sector 22.

Work For the Next 2-3 Months:

Production of blocks for Sectors 13-64 will continue at UIUC. The current rate of block production is close to the level of 66 blocks per week required to complete all of the blocks by the end of 2021, and with the addition of the new machinist, should reach be able to reach and maintain this goal. Production of the high rapidity blocks for Sectors 13-64 will also continue at Fudan at a higher rate now that the Chinese New Year is over and we expect that it will reach the rate of 24 blocks per week required to allow full sector production at BNL to continue.

Module production and sector assembly will continue at BNL. Block production and delivery is on track and there are sufficient parts to complete up to Sector 19. We currently don't have enough preamps to complete all of these sectors. However, we expect that more preamps will arrive in early April, which will allow us to complete additional sectors (editors note: the EMCal preamps did arrive as expected). We will need additional preamp deliveries in order to resume full sector production and stay on schedule.

Issues:

The status of the three issues of concern from last month is as follows:

1. The issue of needing to hire an additional machinist at UIUC has been resolved and another machinist will start working full time in early April.
2. Block production resumed at a higher rate at Fudan after the Chinese New Year and we expect them to reach a rate of 24 blocks per week needed to keep up with full sector production at BNL.
3. We received some preamps that allowed us to complete several additional sectors. Currently we have been unable to complete sectors beyond Sector 16 due to a delay in the preamp delivery. However, we are expecting the delivery of additional preamps in early April and that more will become available throughout April and May.

WBS 1.4 Hadronic Calorimeter (L2 Manager: John Lajoie, Iowa State University)

WBS 1.4.1 Inner Hadronic Calorimeter

Current Status:

ISU has contracted with Technical Services, Inc., (TSI) to provide the iHCAL sectors. The delivery schedule has been coordinated with Rutgers to ensure that the parts provided will arrive well in advance of when they are needed for assembly. The Rutgers shops have completed all the absorber end plates and 16 pairs of electronics shelves, which have been shipped to TSI. Due COVID-related furloughs the sector endplates have been subcontracted to UT-Austin, and the first group of eight pairs are expected to be shipped by April 30th. First article inspection at TSI is still expected by 5/21/2021 with delivery of the first eight sectors to BNL shortly thereafter.

The iHCAL end rings have been received by BNL (see Figure 7) and are currently undergoing inspection.

Work for the Next 2-3 Months:

ISU and Rutgers will continue to coordinate with TSI to ensure good communication and adherence to the production schedule. Sector assembly will begin in earnest in the mid- to late-July time frame, driven by the availability of components.

Issues:

The COVID-19 pandemic can potentially have a negative schedule impact on the inner HCAL assembly schedule due to the availability of student labor in summer 2021. It will be critical that iHCAL sector assembly proceed quickly to avoid delays in the sPHENIX installation schedule.

WBS 1.4.2/3/4 Outer Hadronic Calorimeter

Current Status:

Assembly of the last oHCAL sector was completed on March 26th, 2021. The focus of the activity in the bldg. 912 factory has now shifted to burn-in tests of the sectors now that a burn-in test rack is available. Two sectors have been completed – the first required the replacement of two SiPMs, while the second did not require re-work after burn-in. Work is also underway to complete analysis of the cosmic ray and LED data and prepare the initial calibration constants for the sPHENIX offline database.

The full shipment of high-strength endplates, splice plates, and pucks and pins for oHCAL assembly have all passed QA inspection and are available for oHCAL installation later this year.

Work for the Next 2-3 Months:

Over the next several weeks, work will continue in the oHCAL factory to burn-in the oHCAL sectors prior to the beginning of OHCal sector installation on the sPHENIX carriage in Building 1008.

Issues:

None.

Figure 7: The inner HCAL end rings, received at BNL on 4/22/2021 from Astro Machine Works (a little less than two months early). The end rings are currently undergoing inspection at BNL.

WBS 1.5 Calorimeter Electronics (L2 Manager: Eric Mannel, BNL)

Current Status:

All electronics and cables needed to assemble the oHCal have been delivered to the HCal group. Delivery of the production orders for the EMCal SiPM daughterboards and preamps from the assembly house continues with an expected final delivery in April of 2021. Testing of both the EMCal SiPM daughterboards and preamps continues with a high yield rate. Delivery of the internal signal cables continues on schedule with 80% of the cables delivered and expected delivery of the final cables in April 2021.

The final delivery of all the bias supplies for the EMCal and HCal was received in March. The vendor for the LV bulk supplies has started to ship and has updated the delivery schedule with all supplies shipped by early May. The requisition for the EMCal and HCal external signal cables was submitted at the end of March 2021. Work continues on the assembly of the HCal burn in rack which will be used to power the HCal once it is installed. Design of the EMCal Digitizer racks and HCal Digitizer and Control racks is being finalized to allow for the start of assembly in April of 2021. Procurement documentation for EMCal and HCal external power and communications cables was started.

Columbia University purchasing department has started to issue purchase orders for components needed for the production of the full digitizer electronics. Parts deliveries are scheduled to start over the next 3 months. The Colorado group continues to refine the testing and documentation process for the digitizer boards.

Work for the next 2-3 months:

Work over the next 3 months will be focused on the continued testing of assembled EMCal and HCal sectors and design and construction of racks for on-detector electronics. This work includes:

1. Testing of EMCal SiPM boards and preamps
2. Complete the building of the HCal power rack and transport it to 912
3. Build the first Digitizer racks with a full crate operational.
4. Place orders for external power and communication cables.
5. Production of low voltage distribution systems.
6. Production of the digitizer system
7. Rack assembly

Issues:

- COVID-19 travel and work restrictions will impact the short-term schedule for testing of delivered electronics.

WBS 1.6 DAQ/Trigger (L2 Manager: Martin Purschke, BNL)

Current Status:

We have been working with the engineers from the Collider-Accelerator Department to plan the support, power, and cooling needs for the DAQ machines that are already partially installed. The plan is to create a so-called "hot box", where all hot-air exhaust goes into a sealed volume between two rows of racks, and a dedicated hot-air return duct takes the hot air out and back to the A/C units. This is conceptually shown in Figure 8.

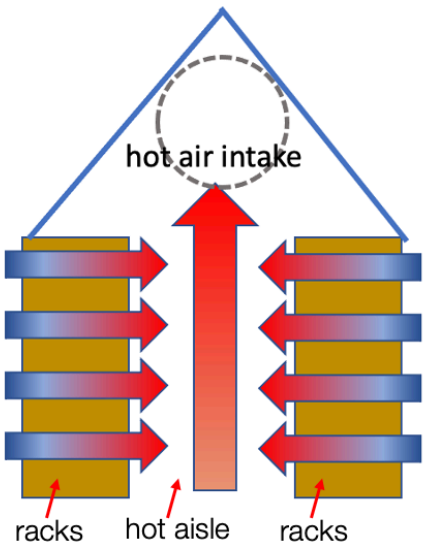


Figure 8: Concept of the enclosed "hot box"

With space and budget constraints, and the existing duct layout we will be able to implement this approximately, with some compromises that will have a negligible impact on the cooling efficiency and thermal management. Figure 9 shows the envisioned layout of the various types of racks and what they hold.

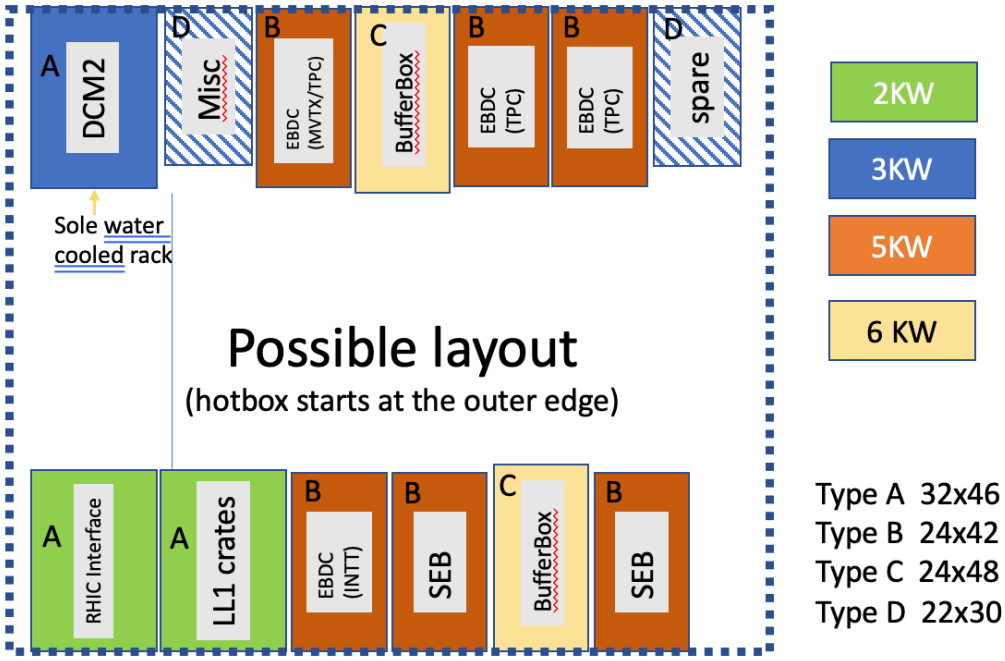


Figure 9: Top view of the envisioned rack layout in the "hot box". There are different types of racks depending on what thy hold, and different power requirements (color-coded). The design if the A/C ducts has started and will be ready to be installed in about 2 months.

A number of add-on prototype cards for the Global Level 1 and Global Timing Module (both functionalities are now combined in the same unit) have been received back from the assembly house and are being tested. Those make the full set of transceivers of the FPGA board available and provide inputs for the busy signals from the calorimeters and the TPC front-ends.

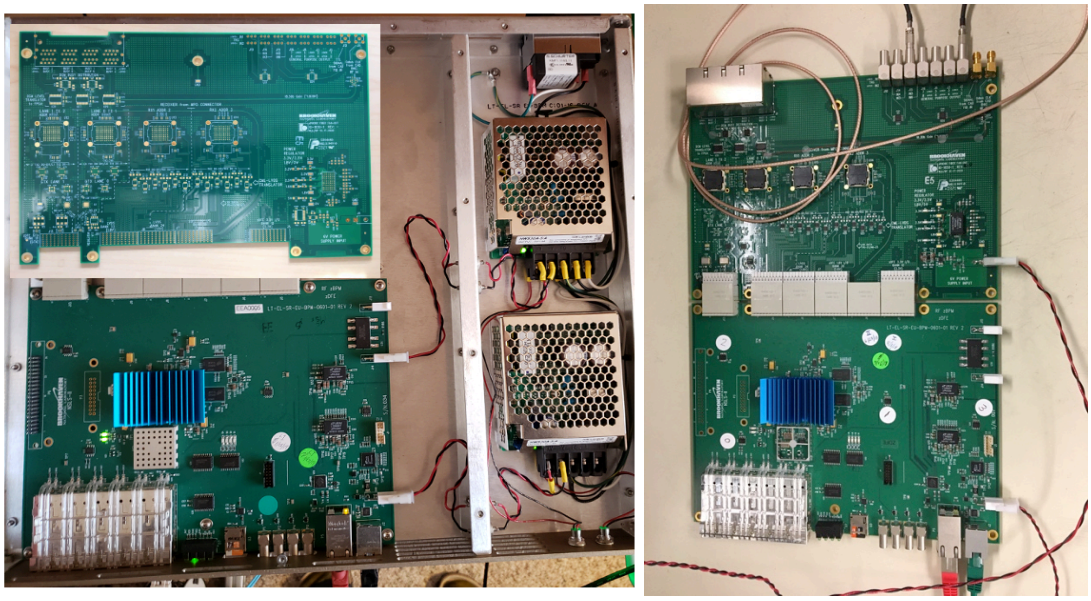


Figure 10: Left: an older “photo-shopped” assembly with the then still unassembled board and how it will go into the FPGA unit in its case. Right: the actual board attached to the FPGA unit being tested (not in a case).

Figure 10 shows on the left an older “photo-shopped” assembly with the then-unassembled board and how it will go into the FPGA unit in its case. The right side shows the actual board attached to the FPGA unit being tested (not in a case). The board will be available soon and will enable a number of tests that were not easily possible before, such as speed and throughput tests that need the busy inputs.

The next test we will conduct is the so-called “slice test”, referring to reading out a complete slice (1/24) of the TPC. Figure 11 shows the setup conceptually.

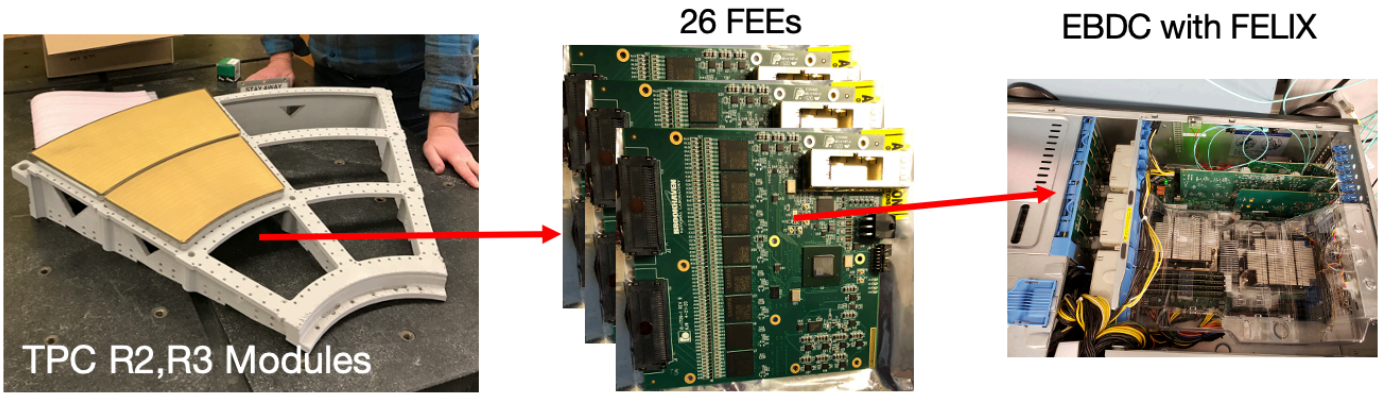


Figure 11: The layout of the “slice test”, which will instrument one full sector of the TPC (1/24 of the total) with 26 front-end boards read out with an EBDC PC. The eventual setup will have 24 such complete units.

Work for the next 2-3 months:

The delivery of more computer racks is expected in a few weeks. This will take some time to install and set up the hardware, and then set up the networks and install the operating system on the PCs. Concurrently, we will work on the preparations for the slice test, and finalize the engineering for the "hot box".

There was only minimal impact due to COVID-19. A lab that had to be sanitized was inaccessible for only one day.

Issues

None

WBS 1.7 Minimum Bias Trigger Detector (L2 Manager: Mickey Chiu, BNL)

Current Status:

We are assembling the test-stand for the chain-test of the prototype MBD electronics with the BBC detector at BNL. The testing will be done in the sPHENIX BBC/TOF lab. There was a Local Level 1 Trigger Final Design Review on March 1. The basic design of the MBD LL1 trigger has been laid out, but there remains much to be done to verify the algorithm in simulation, and also to program the firmware and test it. BNL and Columbia University scientists have started regular conversations on developing the MBD LL1 trigger and plans for its testing. Columbia University, Nevis Labs has completed the contract for purchasing the final MBD production electronics. We are in the beginning stages of the fabrication of the final MBD electronics.

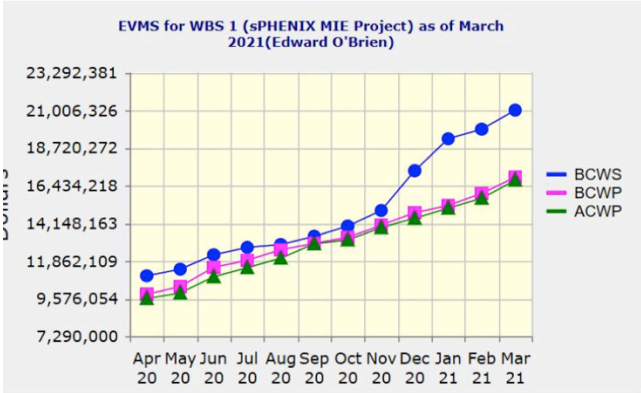
Work for Next 2-3 Months:

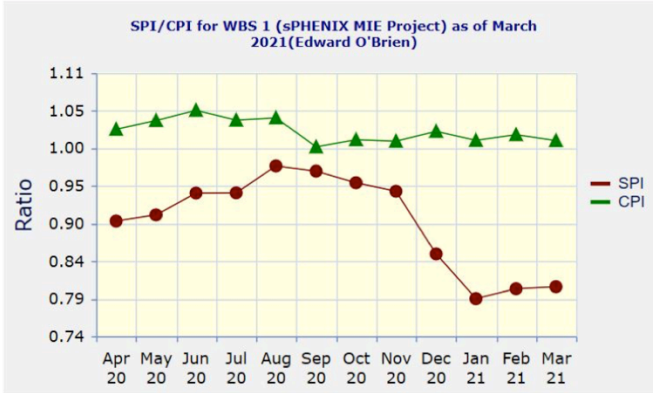
The MBD electronics chain test is being worked on, and is planned to be done by the end of June. BNL personnel continue to meet weekly with grad students from Howard and Florida A&M Univ to train them on the MBD and the skill set required for testing and eventually for operating the MBD. The current plan is for the students to come to BNL in the summer around July, so that they can test the production electronics. We will also be training the students on the MBD simulation so that they can participate in the trigger simulation. Nevis personnel will continue to oversee the procurement of the production MBD electronics. It seems likely that the production electronics will arrive a little later than July, so we are making plans for a new schedule once we have firm dates.

Issues:

None

SPI and CPI Trends





AC: $24,853,936 **EAC:** $24,593,066 **VAC:** $260,870

Cumulative SPI	Cumulative CPI
0.81	1.01

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

Cumulative BCWS (Scheduled)	$21,016,072
Cumulative BCWP (Performed)	$16,947,654
Cumulative ACWP (Actual)	$16,771,625

March 2021 Cost Performance Report

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	1,849,785	1,849,785	1,726,098	0	123,688	1,951,679	1,827,991	123,688	1.00	1.07
1.02A TPC	4,431,951	3,229,292	2,895,830	-1,202,659	333,463	5,026,775	4,578,180	448,596	0.73	1.12
1.03A EMCal	5,334,890	4,938,436	5,254,389	-396,453	-315,953	6,070,008	6,388,648	-318,640	0.93	0.94
1.04A HCal	2,828,365	2,897,873	3,000,967	69,508	-103,093	4,099,592	4,202,685	-103,093	1.02	0.97
1.05A Calorimeter Electronics	5,664,883	3,407,341	3,222,397	-2,257,542	184,944	6,290,621	6,127,276	163,345	0.60	1.06
1.06A DAQ & Trigger	736,028	525,778	592,425	-210,250	-66,647	1,245,090	1,316,323	-71,232	0.71	0.89
1.07A MinBias Trigger Detector	170,170	99,148	79,520	-71,022	19,627	170,170	151,963	18,207	0.58	1.25
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	21,016,072	16,947,654	16,771,625	-4,068,418	176,029	24,853,936	24,593,066	260,870	0.81	1.01
f. Contingency						2,146,064				
g. TOTAL	21,016,072	16,947,654	16,771,625	-4,068,418	176,029	27,000,000				
h. RECONCILIATION TO CONTRACT BUDGET BASELINE										
a. VARIANCE ADJUSTMENT				0	0					
b. TOTAL CONTRACT VARIANCE				-4,068,418	176,029	0	0	0		

CLASSIFICATION (When Filled In)

$7,821,441	ETC
$7,906,282	BCWR
27.44 %	% Contingency on ETC
27.14 %	% Contingency on Remaining Work
84.56 %	% Planned
68.19 %	% Complete
67.48 %	% 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

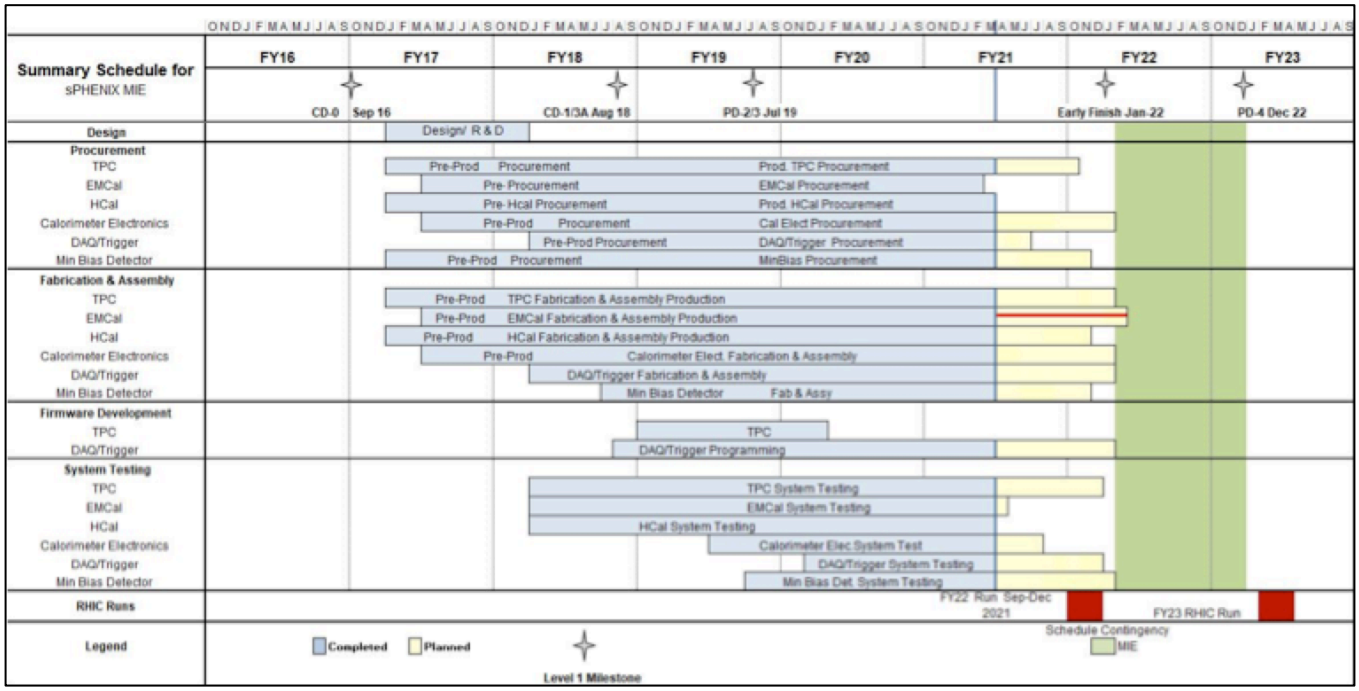
L1 & L2 Milestones

#	WBS	Milestone Name	Target Milestone Date	Forecast	Actual Finish	Variance (in work days)
1	01.01.2001	Approve Project Baseline and Construction PD2/3	30-Sep-19	20-Sep-19 A	20-Sep-19	6
2	01.02.02.02	Production Readiness Review - TPC Module Factories	31-Dec-19	17-Dec-19 A	17-Dec-19	8
3	01.03.02.03.02	EMCal Preproduction Sector 0 Assembled	31-Dec-19	25-Nov-19 A	25-Nov-19	23
4	01.02.06.02	Production Readiness Review - TPC DAM	28-Feb-20	04-Feb-20 A	4-Feb-20	16
5	01.05.02.03	HCal Preproduction FEE Complete	30-Apr-20	22-Jan-20 A	22-Jan-20	70
6	01.05.02.01	EMCal Electronics Preproduction Complete	29-May-20	28-May-20 A	28-May-20	0
7	01.03.01.03.01	EMCal W Powder Acquisition Complete	30-Jun-20	15-Jun-20 A	15-Jun-20	11
8	01.03.02.03.03	EMCal Production Readiness Review Blocks/Modules/Sectors Complete	31-Jul-20	30-Jul-20 A	30-Jul-20	1
9	01.02.05.03	SAMPA ASIC Performance Accepted	30-Sep-20	29-May-20 A	29-May-20	86
10	01.05.2001	EMCal/HCal SiPM Sensor Procurement Complete	30-Oct-20	28-Feb-20 A	28-Feb-20	171
11	01.05.02.04	HCal SiPM Boards Assembly Complete	30-Nov-20	22-Sep-20 A	22-Sep-20	45
12	01.04.04.02	First Outer HCAL Sector and Splice Plates Ready to Install	30-Apr-21	25-Feb-21 A	25-Feb-21	46
13	01.05.02.02	EMCal SiPM Boards Production Complete	27-May-21	30-Jun-21		-24
14	01.02.01.06	GEM Production Complete	31-May-21	15-Apr-21		31
15	01.03.01.03.01	EMCal Scintillating Fiber Acquisition Complete	31-May-21	25-Feb-21 A	25-Feb-21	67
16	01.06.02.03	Trigger LL1 Preproduction complete	28-Jun-21	29-Jul-21		-23
17	01.05.02.04	HCal Electronics Complete: Production	30-Jun-21	7-May-21		36
18	01.04.2001	Inner HCAL Support Structure Ready for Installation	9-Aug-21	19-Nov-21		-72
19	01.02.06.03	TPC DAM Felix 2.0 Production Complete	31-Aug-21	31-Aug-21		-1
20	01.05.03.02	Calorimeter Electronics Complete	28-Oct-21	28-Jan-22		-61
21	01.05.02.02	EMCal Electronics Complete	28-Oct-21	28-Jan-22		-61
22	01.02.01.08	TPC Ready to Install (Assembly Complete)	29-Oct-21	28-Dec-21		-39
23	01.02.05.04	TPC FEE Production Complete	29-Oct-21	15-Dec-21		-31
24	01.04.04.02	Last Outer HCAL Sector Ready to Install	29-Oct-21	29-Mar-21 A	29-Mar-21	150
25	01.02.06.03	TPC DAM Production Complete	12-Nov-21	14-Dec-21		-21
26	1.07	MinBias Detector Ready to Install	14-Dec-21	19-Jan-22		-24
27	01.06.01.03	DAQ Production: DAQ Ready for Operation	30-Dec-21	19-Jan-22		-13
28	01.06.03.03	GL1 Ready to Operate	24-Jan-22	5-Jan-22		11
29	01.06.02.04	LL1 Trigger Production Complete	25-Jan-22	20-Dec-21		22
30	01.06.02.04	LL1 Ready to Operate	25-Jan-22	20-Dec-21		22
31	01.03.02.03.03	EMCal Ready to Install	4-Feb-22	4-Feb-22		-1
32	01.01.2001	Early Project Completion	7-Feb-22	7-Feb-22		0
33	01.01.2001	Approve Project Closeout PD-4	30-Dec-22	29-Dec-22*		0

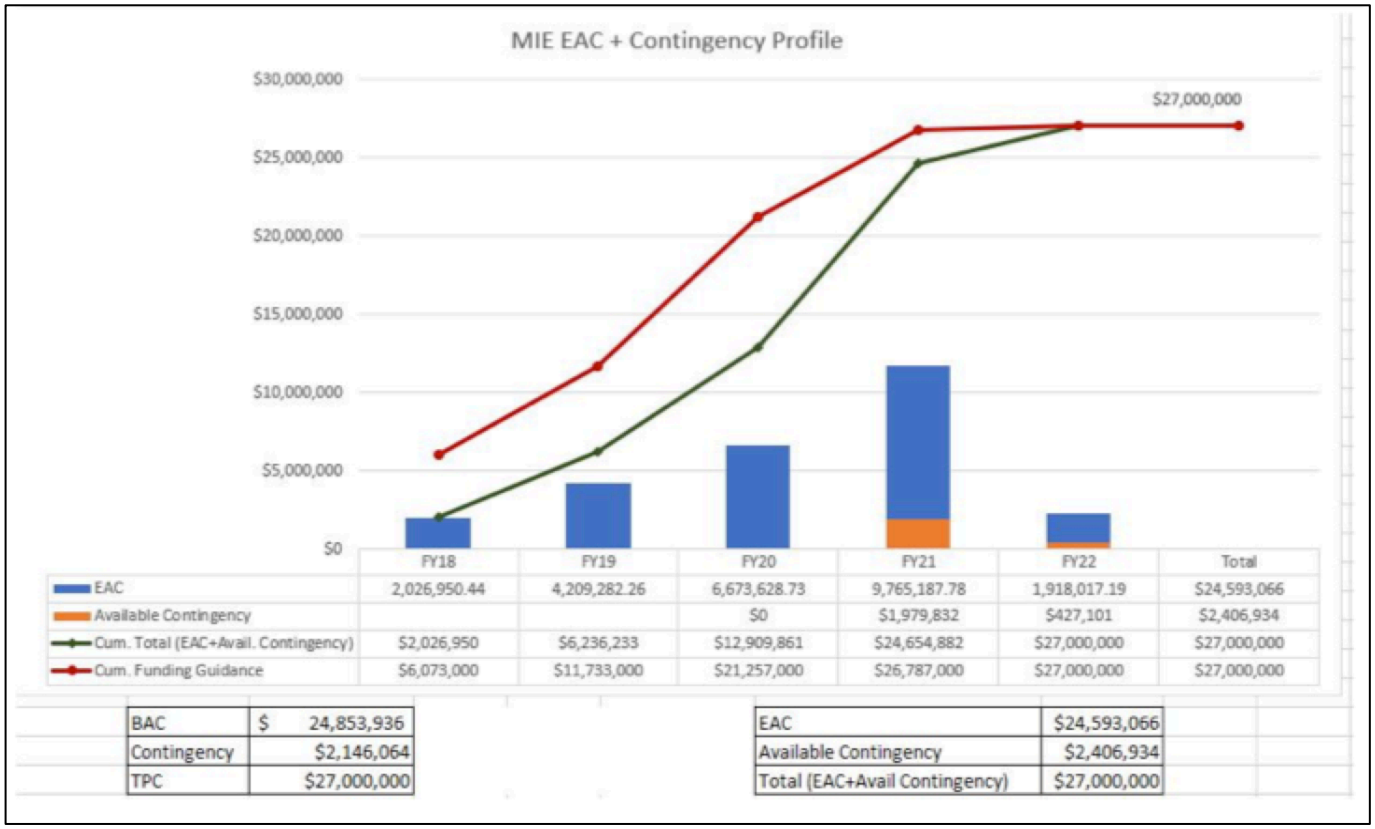
sPHENIX Budget Profile:

Funding Profile At Year k$								
	Prior Yrs	FY17	FY18	FY19	FY20	FY21	FY22	Total
R&D		1,513	4,260	350				**6,123**
CDR		100	200					**300**
PED								
Pre-ops								
OPC (R&D+CDR)		**1,613**	**4,460**	**350**				**6,423**
TEC				**5,310**	**9,524**	**5,530**	**213**	**20,577**
Total Project Cost		**1,613**	**4,460**	**5,660**	**9,524**	**5,530**	**213**	**27,000**

Summary Schedule with critical path



Estimate at Completion Profile



	FY18	FY19	FY20	FY21	FY22	Total
EAC	2,026,950.44	4,209,282.26	6,673,628.73	9,765,187.78	1,918,017.19	$24,593,066
Available Contingency			$0	$1,979,832	$427,101	$2,406,934
Cum. Total (EAC+Avail. Contingency)	$2,026,950	$6,236,233	$12,909,861	$24,654,882	$27,000,000	$27,000,000
Cum. Funding Guidance	$6,073,000	$11,733,000	$21,257,000	$26,787,000	$27,000,000	$27,000,000

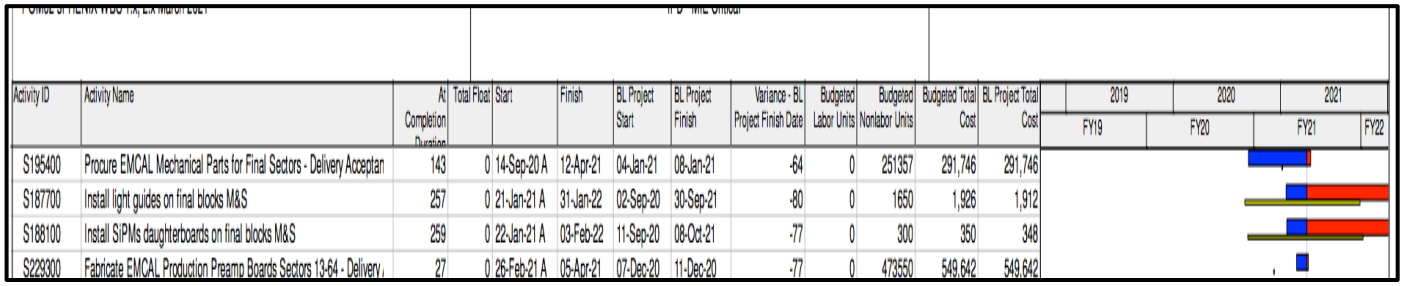
BAC	$ 24,853,936
Contingency	$2,146,064
TPC	$27,000,000

EAC	$24,593,066
Available Contingency	$2,406,934
Total (EAC+Avail Contingency)	$27,000,000

Baseline/Contingency Log

Baseline/Contingency Log - sPHENIX MIE Project							
Date	PCR ID	PCR Title	WBS affected	sPHENIX MIE Baseline Cost	PCR Change	Contingency	Total Project Cost
20.09.2019	Approved MIE	Setting up Baseline	all	$22,169,490		$4,830,510	$27,000,000
24.09.2019	007A	Hcal Scin Tiles placed Contract delivery schedule	1.04 HCal	$22,132,844	($36,646)	$4,867,156	$27,000,000
31.01.2020	008A	OHCal Sci.Tiles delivery schedule update	1.04 HCal	$22,132,943	$100	$4,867,056	$27,000,000
27.02.2020	009A	Extending the lead time for IHCal Support Rings	1.04 HCal	$22,132,943	$0	$4,867,056	$27,000,000
31.03.2020	011A	Added management labor for EMCal block production. EMCal Powder and TPC Sampa Cost and Delivery Schedule update	1.02 TPC and 1.03 EMCal	$22,193,813	$60,870	$4,806,187	$27,000,000
28.04.2020	013A	EMCal Block assembly contract details schedule update	1.03 EMCal	$22,195,549	$ 1,736	$4,804,451	$27,000,000
27.05.2020	014A	EMCal Light guides delivery schedule; EMCal SiPM daughterboards for Sectors 13-64 contract schedule	1.03 EMCal and 1.05 Cal E	$22,176,963	$ (18,586)	$4,823,037	$27,000,000
19.06.2020	105A	COVID-19 Schedule Adjustments	All	$22,198,743	$ 21,780	$4,801,257	$27,000,000
30.10.2020	017A	Risk Reduction and Realization	1.2; 1.3; 1.4; 1.5	$24,309,836	$ 2,111,093.00	$2,690,164	$27,000,000
31.12.2020	019A	Additional tech labor for EMCal and HCal	1.3; 1.4	$ 24,531,362	$ 221,527	$ 2,468,638	$ 27,000,000
31.01.2021	020A	Move out the Early Project Completion milestone; add tech labor	1.1; 1.2; 1.3; 1.4	$ 24,897,760	$ 366,398	$ 2,102,240	$ 27,000,000
28.02.2021	021A	IHCal Support Rings Placed Contract	1.4.1	$ 24,853,936	$ (43,824)	$ 2,146,064	$ 27,000,000
31.03.2021	022A	IHCal Support Structure Placed Contract	1.4.1	$ 24,853,936	$ -	$ 2,146,064	$ 27,000,000

Critical Path



Activity ID	Activity Name	At Completion Duration	Total Float	Start	Finish	BL Project Start	BL Project Finish	Variance - BL Project Finish Date	Budgeted Labor Units	Budgeted Nonlabor Units	Budgeted Total Cost	BL Project Total Cost
S195400	Procure EMCAL Mechanical Parts for Final Sectors - Delivery Acceptan	143	0	14-Sep-20 A	12-Apr-21	04-Jan-21	08-Jan-21	-64	0	251357	291,746	291,746
S187700	Install light guides on final blocks M&S	257	0	21-Jan-21 A	31-Jan-22	02-Sep-20	30-Sep-21	-80	0	1650	1,926	1,912
S188100	Install SiPMs daughterboards on final blocks M&S	259	0	22-Jan-21 A	03-Feb-22	11-Sep-20	08-Oct-21	-77	0	300	350	348
S229300	Fabricate EMCAL Production Preamp Boards Sectors 13-64 - Delivery	27	0	26-Feb-21 A	05-Apr-21	07-Dec-20	11-Dec-20	-77	0	473550	549,642	549,642

Variance Analysis

Reporting Period: 3/1/2021 - 3/31/2021

sPHENIX MIE Project (Edward O'Brien [18368])

	BCWS	BCWP	ACWP	SV in $	SV in %	CV in $	CV %	SPI	CPI
Current:	1,163,200	993,150	1,112,632	-170,050	-15%	-119,482	-12%	0.85	0.89
Cumulative:	21,016,072	16,947,654	16,771,625	-4,068,418	-19%	176,029	1%	0.81	1.01
	BAC								
At Complete:	24,853,936								

Threshold(s) Exceeded: Cumulative Schedule

Explanation of Variance/Description of Problem:
WBS 1.2.1 TPC Mechanics: One activity, S120100 Production of GEM foils, has an SV of -$44,835, due to late delivery of GEM foils manufactured at CERN. The delay is due to a COVID-related shutdown of the CERN factory and a subsequent four-month delay in GEM foil manufacture. WBS 1.2.2 TPC GEM Modules R1: The TPC R1 padplanes activity S125100, mentioned in prior variance reports, is finally complete. Two activities were delayed by late arrival of TPC R1 padplanes. These are S125500 TPC R1 modules build, with SV = -$26,663 and S125600 TPC R1 Modules test, with SV = -$21,649. The total SV resulting is -$48,312. The layout of the R1 padplane, the smallest of the three types, was hampered by signal trace routing issues which did not conform to design rules required by the printed-circuit board manufacturer. WBS 1.2.5 TPC Front End Electronics: There are five activities with significant SV. They are: activity S136500 TPC FEE Cooling System, SV = -$57,393, activity S141500 TPC FEE Production components (optical transceivers), SV =-$22,999, activity S141800 TPC FEE Production Components, SV = -$52,623, activity S142500 TPC FEE Low Voltage Power system, SV = -$205,153, activity S143200 TPC FEE Production boards and assembly, SV = -$35,049, and activity S143250, TPC FEE components, SV = -$79,822. The net SV is -$453,039. WBS 1.2.6 TPC Data Aggregator Modules: Three activities contribute to the SV: activity S147300 FELIX 2.0 production board, SV = $30,262, activity S147370 FELIX 2.0 board optical components, SV =-$93,719, and activity S148400 EBDC computers and peripherals, SV =-$244,769. WBS 1.2.7 TPC Support Systems: There are three areas of effort. The TPC Lasers delivery has started but only the first articles have been delivered, SV =-$190,452. The TPC Gas System has procured and received some 60% of the components but still needs to place requisitions for the balance, SV =-$44,121. The TPC Cooling system has not procured the high value elements including the chiller/re-circulator, SV =-$73,653. The total SV for these key items is -$308,226, some 20% smaller than the prior month due to several components being procured during March. WBS 1.3.1 EMCal Blocks: There are four main items causing the SV. The S171800 Epoxy is only 48% complete, SV =-$32,828. Molds S172500 and fiber assemblies S172800 are behind schedule, SV =-$8,159 and -$4,241 respectively. The S174600-S176200 Blocks for Sectors 29-45 are not complete, SV =-$86,991, nor is their shipping to BNL, SV =-$19,166. The total SV for these items is -$151,385. WBS 1.3.2 EMCal Modules and Sectors: The S187400 Production Light Guide contract is only 45% complete, SV = -$132,071. The S195400 Mechanical parts for Final Sectors are only 85% complete, SV = $43,762. The S196100 Cooling System for Final Sectors was only 31% complete, SV = -$56,776. The total of these SVs is -$232,609, about 15% less than the prior month. WBS 1.4.2 Outer HCal Mechanics: The S205100 Splice Plates, which had an SV = -$239,626, last month, were delivered, removing this source of schedule variance. WBS 1.4.4 Outer HCal Sector Assembly and Testing: The S209800 – S210200 assembly and testing of the production Outer HCal Sectors was completed ahead of schedule, SV = $69,508. WBS 1.5.2 Calorimeter Front End Electronics: activity S227605 EMCal SiPM daughterboards part 2, SV = -$16,244, activity S229300 EMCal preamplifiers only 10% delivered, SV = -$494,678, activity S231800 EMCal internal cables are only 75% complete, SV = -$72,048, activity S233200 EMCal external cables are not complete, SV = -$205,854 activity S233250 EMCal trunk signal cables are not complete, SV = -$384,292, activity S234000 EMCal Bias power supplies completed early, SV = $155,680 activity S234100 EMCal LV power system sectors 13-64 only 25% complete, SV =-$29,452, activity S244400 HCal External cables are only 50% complete, SV = -$50,970, and activity S244450 HCal trunk signal cables not complete, SV =-$73,766. WBS 1.5.3 Calorimeter Digitizers: activity S252700 Digitizer Parts, SV = -$678,538, activity S252800 Digitizer Boards, SV = - $149,785, and activity S252900 Digitizer Assembly, SV = -$231,066 WBS 1.6.1 Data Acquisition: activity S255900 Production boards not complete, SV = -$121,503, activity S256700 crates not complete, SV = -$74,284, activity S258400 Assembly and Trigger Processor boards completed early, SV = $113,823, activity S258700 jSEB slow control boards not complete, SV = -$19,181, and activity S259500 Buffer Box procurement completed early, SV = $41,513 WBS 1.6.2 Local Level-1 Trigger: Activity, S263600 Preproduction Local Level-1 trigger, is not complete, resulting in SV = -$69,641. WBS 1.6.3 Global Level-1 Trigger: Activity S267600 Production of final GL1 is not complete, SV =-$32,673. WBS 1.6.4 Timing System: Activity S270300 Production of Timing System is not complete, SV =-$48,284. WBS 1.7 Min Bias Trigger Detector: Activity S273500 Min/Bias production digitizers is not complete, SV = -$17,143, and activity S273600 MBD Shaper/Disc Board is not complete, SV = -$53,879

Impact:

WBS 1.2.1 TPC Mechanics: None as yet. All delivered GEM foils, some 71% to date, have been mounted on frames and prepared for assembly into readout modules for the TPC. WBS 1.2.2 TPC GEM Modules R1: None as yet. The rest of R1 module construction is proceeding. Pad planes are to be attached to the modules as a late step in the module assembly sequence. Positive float remains. WBS 1.2.5 TPC Front End Electronics: None as yet WBS 1.2.6 TPC Data Aggregator Modules: None WBS 1.2.7 TPC Support Systems: These are all items being procured well ahead of their needed installation in order to allow for more time to test them on the bench and adjust settings. WBS 1.3.1 EMCal Blocks: None WBS 1.3.2 EMCal Modules and Sectors: None WBS 1.4.2 Outer HCal Mechanics: None WBS 1.4.4 Outer HCal Sector Assembly and Testing: None WBS 1.5.2 Calorimeter Front End Electronics: none except for the EMCal preamps, which are needed by the EMCal sector production line now, meaning 3 sectors of EMCal have not quite been completed due to lack of preamps to finish them. These sectors are set aside pending receipt of the preamps and the EMCal sector line has continued with further sectors. The preamps are added near the end of EMCal sector assembly, meaning most of the sector assembly work can proceed. Adequate space exists to stage these sectors whose completion is pending receipt of preamps. WBS 1.5.3 Calorimeter Digitizers: None presently. The EMCal and OHCal sector production lines have an adequate number of digitizers to perform all needed QA during remaining detector construction. Therefore, the remaining digitizers are only needed by the completion of the MIE project. WBS 1.6.1 Data Acquisition: None. These items do not affect the production schedule for any other MIE items. WBS 1.6.2 Local Level-1 Trigger: None WBS 1.6.3 Global Level-1 Trigger: None WBS 1.6.4 Timing System: None WBS 1.7 Min Bias Trigger Detector: None

Corrective Action:
WBS 1.2.1 TPC Mechanics: The order remains in progress. We are supporting a full-time technician at CERN to speed manufacture of remaining foils. The revised delivery schedule provided by CERN will meet our assembly schedule for the TPC readout modules. WBS 1.2.2 TPC GEM Modules R1: The R1 pad planes have been delivered. The two above activities are now proceeding and will not impede overall TPC construction. WBS 1.2.5 TPC Front End Electronics: All the items covered by these activities are being ordered, with one exception, the optical transceivers, which were tested in February for operation in magnetic field. The manufacturer announced in February that it is replacing this part with a newer and less expensive version; the new variant will have to be the one purchased by sPHENIX and thus also will need to be tested in magnetic field, although no issues are expected based on technical input from the manufacturer. The required design and procurement reviews are complete. The cooling system requires a series of machined parts, for which the procurement is placed, and manufacturing is started. The TPC FEE production components are on order. The TPC FEE Low Voltage power supplies are under contract with the vendor scheduling all deliveries over the next two months. The TPC production board and assembly procurement is progressing, with bids received and a likely vendor identified. The TPC FEE components, mostly the quad transceivers, will be ordered later in the spring because they are added to the assembled boards by hand after the automatic board assembly is complete. WBS 1.2.6 TPC Data Aggregator Modules: The EBDC computer prototype passed all tests. The production order has now been submitted to Procurement and is out for bid. The FELIX production board order is submitted; the components are in hand and thus the activity is 80% complete, and only board preparation and assembly remains; these activities are underway. The FELIX optical components are fiber optics and specialized connectors to group and route signals from the TPC FEE cards (WBS 1.2.5) to the FELIX boards. The topology of these connectors must accommodate a board used to reprogram the FEE cards in case of radiation-induced single event upsets (SEUs); the architecture of this board was determined at the beginning of March. This fiber topology was updated and the bill of materials for the fiber optic components was revised during March. WBS 1.2.7 TPC Support Systems: The Preliminary Design reviews are complete and all three of these subsystems have moved to acquiring first articles. Operation of the first laser under the necessary field conditions was demonstrated. The Final Design reviews and the Procurement Readiness reviews for the laser system, which has the remaining items with multi-month procurement lead times, were held in March. The procurement for the chiller/re-circulator has now been started. WBS 1.3.1 EMCal Blocks: The Epoxy must be bought within a few weeks of use, due to shelf-life issues. It is a commodity item and is purchased on an as-needed basis. The delayed Blocks were caused by personnel absences due to the COVID-19 pandemic. Block

production resumed over the summer of 2020 and returned to planned production rates in the Fall. This particular SV will persist until about 2 weeks before the Project is complete, at which time Block production will be complete. The Early Completion date for the MIE project was adjusted in January 2021 to reflect this. WBS 1.3.2 EMCal Modules and Sectors: The light guide production was suspended at the vendor until QA and tooling-fixture issues were examined and resolved. These issues were addressed over October-December and production deliveries have resumed at the planned rate and ahead of when they are needed to produce sectors. The light guide vendor has qualified more machine shops supplying him to further improve his delivery rate in the future. The mechanical parts are being delivered somewhat ahead of schedule, with all but the sawteeth/strongbacks in fact being complete; the sawteeth delivery schedule is about a month ahead of need-by date. The cooling system components are being manufactured by a local small company at a pace about 2 months ahead of need-by date. WBS 1.4.2 Outer HCal Mechanics: None needed, work is completed. WBS 1.4.4 Outer HCal Sector Assembly and Testing: None needed, work is completed ahead of schedule. Some part of the positive schedule variance will persist until September 2021 which is the planned completion date for this effort. WBS 1.5.2 Calorimeter Front End Electronics: The contract is placed for the EMCal preamplifiers. The vendor has now delivered two small batches, adequate to instrument more than 5 sectors. The vendor has now obtained all the long-lead-time parts for the main EMCal preamplifier production and did start mass production during March. The vendor for the EMCal internal cables has been delivering them regularly on a schedule well in advance of the need for them during EMCal sector construction. The Procurement readiness review was held in January for the external/trunk cable orders, EMCal and HCal, and procurement documents have been delivered to the Procurement group. Potential vendors indicate they can meet the requested delivery schedule for these cables. WBS 1.5.3 Calorimeter Digitizers: The contract for the production digitizers is placed. The vendor indicates they are placing orders for production quantities of all parts but that world-wide supply chains have led to more lead time than foreseen pre-COVID. We continue to monitor the progress by this vendor. WBS 1.6.1 Data Acquisition: None for the activities that were completed early. Procurement documents are being prepared but are not yet complete for the three items which are not complete. WBS 1.6.2 Local Level-1 Trigger: The prototype Local Level-1 trigger board has been under full-speed testing for several months. Results to date indicate it will meet all requirements, completing the above activity. A review held in late February determined that a few small revisions to the board are needed. These revisions are proceeding. The production manufacture is still expected during 2021 based on the existing board assembly house and Bill of Materials. That production will complete this level-3 WBS. WBS 1.6.3 Global Level-1 Trigger: The prototype Global Level-1 Trigger is being used as part of an extended test of electronics for sPHENIX. This test requires multiple front-end cards to operate, respond to triggers and timing signals, and send data to the production DAQ computers correctly over an extended period. This test is continuing as of the end of March. Assuming a positive outcome, the production Global Level-1 Trigger will be assembled using the existing blueprints. WBS 1.6.4 Timing System: The prototype Timing System is being used as part of an extended test of electronics for sPHENIX. This test requires multiple front-end cards to operate, respond to triggers and timing signals, and send data to the production DAQ computers correctly over an extended period. This test is continuing as of the end of March. Assuming a positive outcome, the production Timing System will be assembled using the existing blueprints. WBS 1.7 Min Bias Trigger Detector: The digitizers needed for the MBD are part of the larger digitizers order noted above for WBS 1.5.3 A final design review and production readiness review were held for the MBD shaper/discriminator board in February, no required changes were identified, and the board approved for production procurement. This procurement is being placed with the vendor who prepared and tested the prototype versions. Completion by December 2021 is anticipated.

Prepared By:	**Date:**	**Approved By:**	**Date:**
Irina Sourikova	4/25/2021	Edward O'Brien	4/26/2021