sPHENIX Project Status Report – November 2020

HOST LABORATORY: BROOKHAVEN NATIONAL LAB

FEDERAL PROGRAM MANAGER: ELIZABETH BARTOSZ

BHSO POINT OF CONTACT: ROBERT CARADONNA

CONTRACTOR PROJECT DIRECTOR: EDWARD O'BRIEN

1. **SCORECARD AS OF November 30, 2020**

Current PD:	**2/3**	Date of Current CD/PD approval		September 2019	
Next PD:	**4**	Forecast approval:	**1QFY23**	Baseline:	**1QFY23**
% Complete:	**57.7%**	Planned:		**61.4%**	
ETC:	**$10.3M**	TPC or Cost Range:		**$27.0M**	
Contingency:	**26.1%** on ETC	Float to PD-4 in months:		**11.5**	
Cumulative CPI:	**1.01**	Cumulative SPI:		**0.94**	

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 are implementing a plan to mitigate COVID-19 related delays. The plan includes funding collaborating universities that host sPHENIX fabrication and testing activities to hire additional technicians to replace a shortfall in student labor. In the next two months we will Implement a PCR to realize EMCal technical labor risks that will be mitigated by hiring additional technical labor at BNL.

Most of the recent project activities are associated with production of final detector components. Remaining R&D is limited to electronics and calibration components for the detector, and will be completed in the near future.

The TPC field cage will be assembled at SBU in the coming few months with the field cage pieces being assembled into the final full unit. TPC Fee preproduction boards will all arrive at BNL and testing will be completed. Testing of TPC DAM (FELIX) preproduction electronics will be completed in the near future. Testing of production SAMPA v5 chips will be completed at Lund. The TPC central membrane will have aluminum stripes evaporated onto the central membrane petals. Full-scale production-level GEM framing will commence.

Production of blocks for Sectors 13-64 will continue at UIUC. The rate of block production has been shown to reach the target production rate, but it will require sufficient technical labor to maintain this rate over the long term. Production of the high rapidity blocks for Sectors 13-64 will also continue at Fudan University. Work will continue on EMCal module production and sector assembly at BNL. We expect additional deliveries of light guides in December. Additional technical labor for the EMCal sector factory has been hired by BNL and will begin at the end of December.

A contract will be put in place by ISU for the fabrication of the iHCal frame. Over the next six months work on the outer HCAL will center on production sector assemblies in the HCAL factory. We expect the parts that enable the mechanical assembly of the OHCal sectors into the detector barrel will arrive at BNL in the next 4 weeks. The OHCal parts include the joining plates, pins and pucks.

Calorimeter electronics work over the next 3 months will be focused on the continued testing of preproduction sectors and procurement of production electronics. Tasks include assembly of OHCal cables, testing of EMCal SiPM daughter boards, HCal preamps and LED driver boards, building the first digitizer rack, LVPS system production and ordering external cables.

The DAQ/Trigger group will continue to benchmark the performance of the network switch, "Buffer Box" File Server, Timing system and Global Level 1 system. The Timing System Board will be sent out for fabrication, and work will begin for a second version with additional features. The development of the Local-Level 1 board and firmware will continue.

A Production Readiness Review of the MBD Discriminator/Shaper (D/S) board will be held. System tests of a crate containing multiple MBD D/S boards will continue. The resolution will be checked through a system test of multiple ADC boards. BNL scientists will continue to train grad students from Howard Univ and Florida A&M Univ on testing and operation of the MBD.

3. **STATUS HIGHLIGHTS**

Production components for the sPHENIX detector continue to arrive. The early completion date remains unchanged in November, which indicates that the schedule has stabilized after a 2.5 months of delay in the schedule over the summer due to COVID. The first milestone related to the sPHENIX 2021 PEMP notable has been met. We expect the second milestone related to the sPHENIX 2021 PEMP notable to be met in January. All the OHCal tiles, a CD-3A long-lead procurement, have been delivered by the vendor and testing has been completed at GSU.

The EVMS processing is complete for November. The schedule contingency remains unchanged at 11.5 months and cost performance remained excellent with 26.1% contingency remaining on a project that is now 57.7% complete. Cobra and P6 monthly reports have been uploaded to IPD. There were no PCRs in November.

Each TPC GEM Module factory has framed their first GEMs. Start of full production will begin in the next few weeks. We have added an extra step of QA step in the GEM framing process. GEMs are sent to WSU for hand inspection by our framing expert. Every production R2 and R3 cathode readout pad has been inspected at SBU with 93% of the pad planes passing inspection. TPC Fee preproduction cards are undergoing tests at BNL while additional TPC Fee preproduction boards are being stuffed at the assembly house. All aspects of the TPC Fee preproduction boards have passed initial testing. Initial orders are under way for the TPC gas, cooling, and laser systems components.

EMCal Block production at UIUC continued for Sectors 13-64. By the end of November 17.5 sectors of blocks have been produced with 16 sectors of blocks being shipped to BNL. The rate of blocks produced exceeded the target production rate of 60 blocks per week in late October but dropped off somewhat in

November, partially due to the Thanksgiving holiday. At BNL eight sectors have been completed and assembly is under way for Sector 9. The first eight sectors underwent their initial post production testing and all LEDs and test pulse calibrations were found to be working.

The contract between BNL and Iowa State University (ISU) for the IHCal sector frame construction has been completed. ISU is in the process of preparing an RFQ that will award the IHCal frame fabrication to a machine shop. GSU has completed testing of the scintillating tiles required for the OHCal, with only 98.6% passing the performance tests. OHCal Factory operations at BNL are continuing with technician labor and collaborator support from the NY state area. The first six pre-production sectors have been fully assembled, and the first five have been tested and moved to storage. The high-strength endplates, pucks, and pins needed to begin OHCal barrel assembly are expected at BNL by the end of December 2020.

Testing of the EMCal SiPM daughter boards continues at BNL. The yield is > 99%. Tests of the HCal interface boards is ~30% complete with a yield of > 98%. HCal LED drive boards QA testing has continued with a >99% yield. Assembly of interior cables for the EMCal and HCal continues on schedule. Work continues on finalizing the rack designs and generating the line drawings required to assemble the EMCal and HCal power, slow control and digitizer racks. The crates for the EMCal and HCal racks have been received, with the power modules now scheduled for a February 2021 delivery. The Univ of Colorado group has assembled a test stand and is working to finalize the software and procedures for characterizing the performance of the Calorimeter Digitizer boards. Collaborators at Columbia University, Nevis Labs continue to refine the FPGA firmware for the digitizer system and prepare procurement documentation for long lead-time parts.

DAQ/Trigger equipment including 20 PCs, a new network switch, and a “first article” file server, called a “Buffer Box”, has been received. The setup of the machines continue. We have been able to perform tests with the new equipment and to confirm the performance benchmarks that we had specified. For the file serve we have specified a sustained write data rate of about 4-5 GByte/s to disk. Our bench tests demonstrated that we were able to obtain a write data rate of more than 10 GByte/s. The development of more software for the data acquisition back-end has progressed. The design of an add-on board for the GL1 and Timing System has been completed and is under a final review prior to release for fabrication. The tests for the Local-Level 1 trigger board are ongoing.

The test of reading out from multiple Min Bias Detector Disc/Shaper boards was successful. This test is to check that the additional jitter from propagating the clock . The tests resulted in an average timing resolution of 40 ps, a little worse than the 30 ps without multiple boards, but still well within the KPP spec of 120 ps.

WBS 1.1 Project Management (L2 Manager: Irina Sourikova)

Current Status:

- SPI is 0.94, CPI is 1.01.

Highlights:

- No PCR in November.
- Risk Register updated with new EMCal risk; risk contingency increased.
- EVMS processing complete; schedule contingency reduced by 3 days and cost performance remained excellent.
- Cobra and P6 monthly reports uploaded to IPD.
- November variance reports approved.

Plans for the next 2-3 month:

- Continue monthly EVMS process and Change Control.
- Implement a PCR to realize EMCal technical labor risk.
- Place TEC orders and monitor procurements.

Issues:

- No issues.

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

Current Status:

Each factory has framed their first GEMs and requested start of full production. We have inserted an extra step of QA in that first articles of framed GEMs are now sent to WSU for hand inspection by our framing expert, Oleg Grachov. This final inspection will start the mass framing at each factory.

The evaporator at SBU is completed and under high vacuum for evaporation of Aluminum stripes onto the Central Membrane.

Microscope inspection of every pad on every pad plane identified shorted pairs on 2 R2 and 2 R3 pad planes, making a yield of 28/30 (above our anticipated yield of 26/30).

FEE cards populated locally at BNL instrumentation and also professionally at Edmund Marks are undergoing initial operation and test. Thus far all aspects are found functional and correct.

Orders are under way for the gas, cooling, and laser systems. The philosophy follows an “order at least one of every part” for all systems so that prototyping is available before full orders are placed. Thermal

tests of dummy loads show a very precise match to expectations. A final design review has been scheduled for the cooling system to fee up the purchase of the remaining parts of that system.

The first prototype line laser that is tolerant of magnetic field passed manufacturer tests at 0.7 Tesla and is being shipped to BNL to undergo tests at full field strength.

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 scale production-level GEM framing will commence.

Issues:

COVID Impact: The initial GEM production at CERN was delayed due to the closing of their shop resulting with a delay that has reduced our float to 90 days on GEMs. Thermal tests were held late due to prior unavailability of BNL personnel and a backlog of other projects upon their return to the lab. Population and testing of the FEE card was delayed in exactly the same way. One of these has yet put the TPC on or near the critical path.

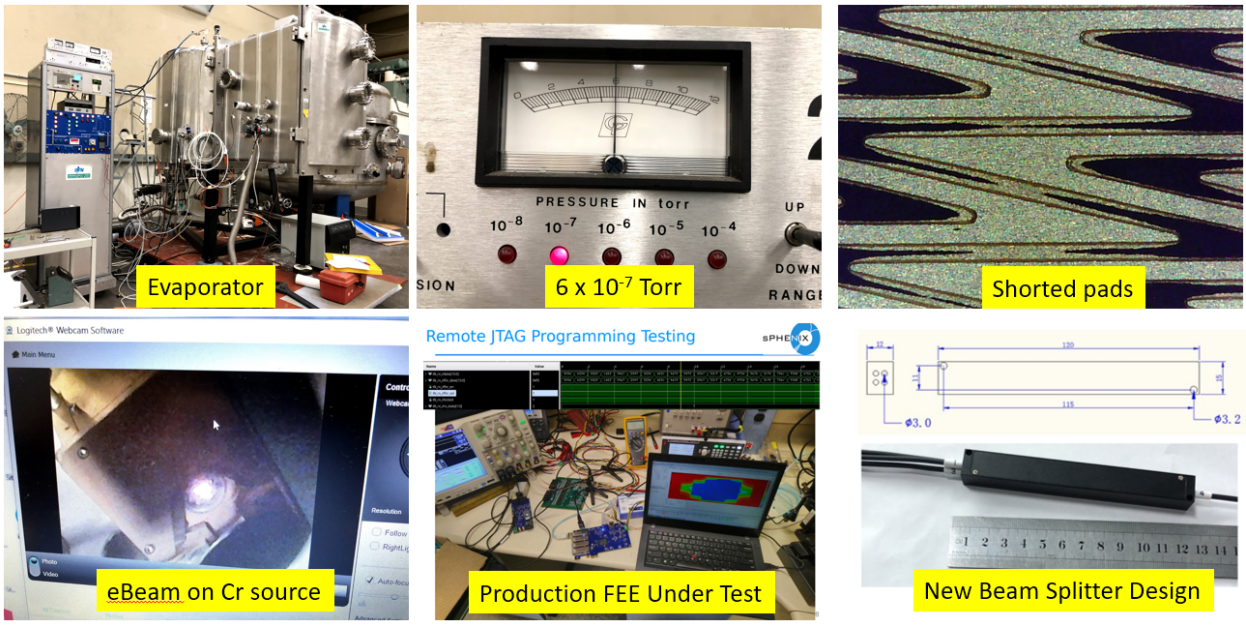


Figure 1. Clockwise from upper left: Evaporator at SBU to be used to place aluminum stripes on the TPC central membrane. A gauge showing vacuum in the evaporator chamber. Inspection of R2 and R3 cathode pad planes. Beam splitter for laser calibration distribution system. Testing of preproduction TPC Fee boards at BNL. Source for metallization deposit on the TPC central membrane. An intermediate chromium layer is needed on the gold plated copper cladding on the central membrane prior to deposition of the aluminum stripes to guarantee good adhesion of the aluminum.

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

Current Status:

Block production at UIUC continued for Sectors 13-64. Figure 2 shows the status as of early December. A total of 397 blocks (5.5 sectors) have been produced and 4.2 sectors have been shipped to BNL. The rejection rate for the 397 blocks was 2.5 % (10 blocks). In addition, 60% of the fiber assemblies for Sectors 13-64 have been filled.

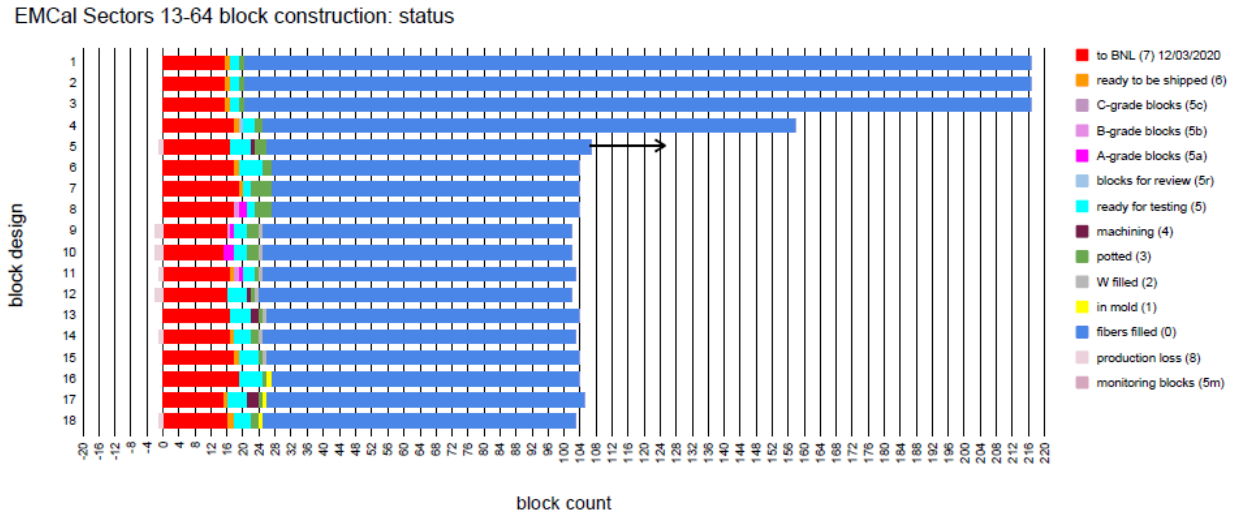


Figure 2. Progress on block production for Sectors 13-64 at UIUC as of early December.

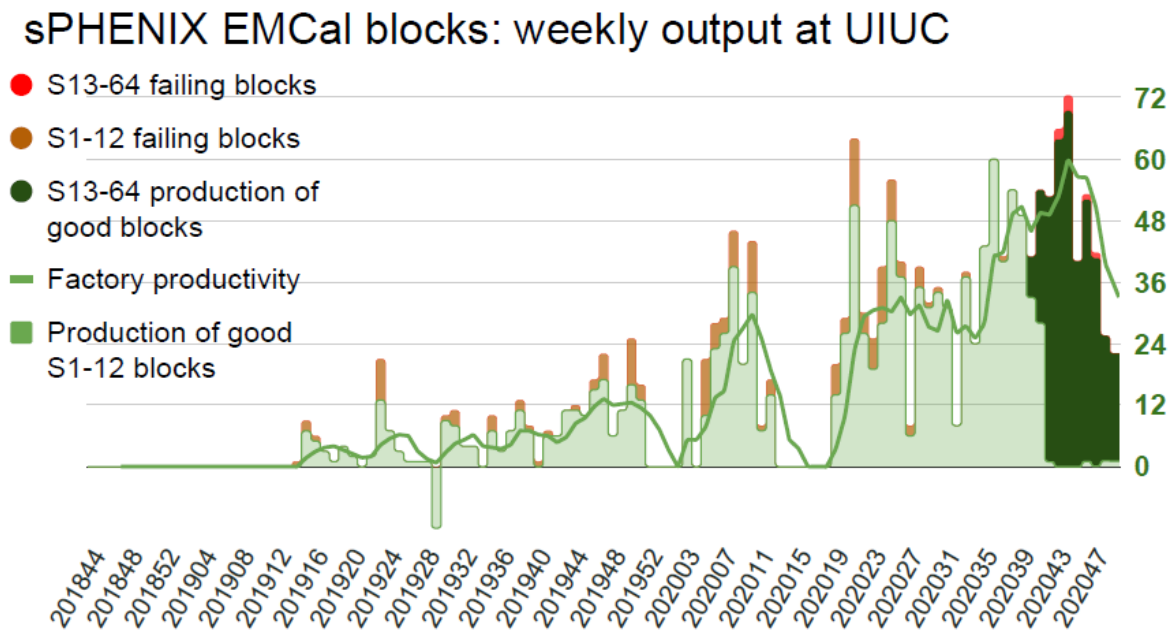


Figure 3. Weekly rate of block production at UIUC (moving average over 4 weeks).

Figure 3 shows the weekly rate of block production at UIUC. The rate of blocks produced exceeded the target production rate of 60 blocks per week in late October but dropped off somewhat in November,

partially due to the Thanksgiving holiday. However, it is expected to increase again in December, assuming sufficient labor resources are available.

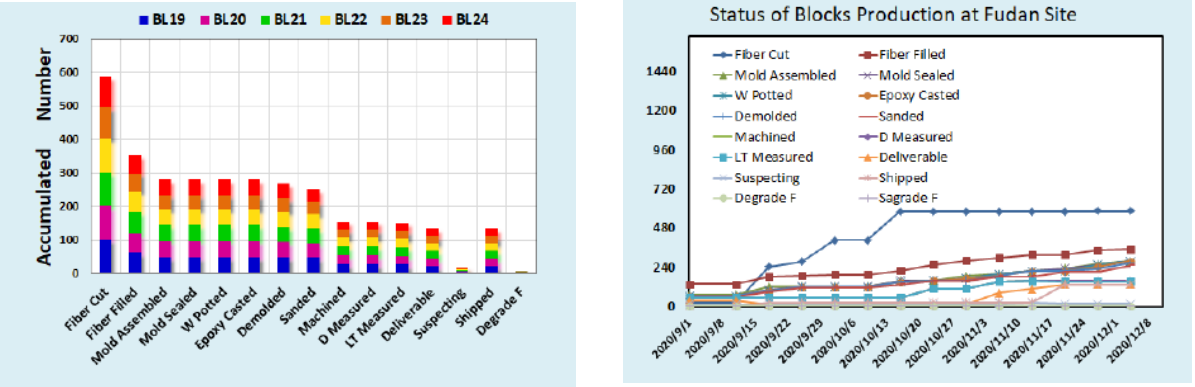


Figure 4. Block production at Fudan. Left show the total number of blocks at various stages of production. Right shows production and shipment per week.

Block production also continued at Fudan as shown in figure 4. The rate of production reached a total of 24 blocks per week, which is the rate needed to keep up with full-scale production at UIUC. The first shipment of 109 blocks sent directly from Fudan to BNL was received in good condition. These blocks will be installed in the outer rapidity regions of Sectors 13-17.

Work on module production and sector assembly continued at BNL. A total of 28 shipments of blocks from UIUC have now been received. Figure 5 shows the status of the various stages of module production. All of the modules for Sectors 1-9 have been completed and work is continuing on the modules for Sector 10. We have enough light guides on hand to complete approximately half of Sector 10 and are expecting a shipment of more in early December.

Figure 6 shows the status of sector assembly. Eight sectors have been completed and assembly is under way for Sector 9. The first eight sectors underwent their initial post production testing and all LEDs and test pulse calibrations were found to be working. Some minor problems are being corrected. A burn-in test station is being prepared that will accommodate up to 6 sectors and allow long term testing under simulated operating conditions. A rotation fixture is also being designed that will allow testing each sector in different orientations as they will be installed in sPHENIX. A similar fixture will be constructed that will be used for cosmic ray testing of some sample of the sectors.

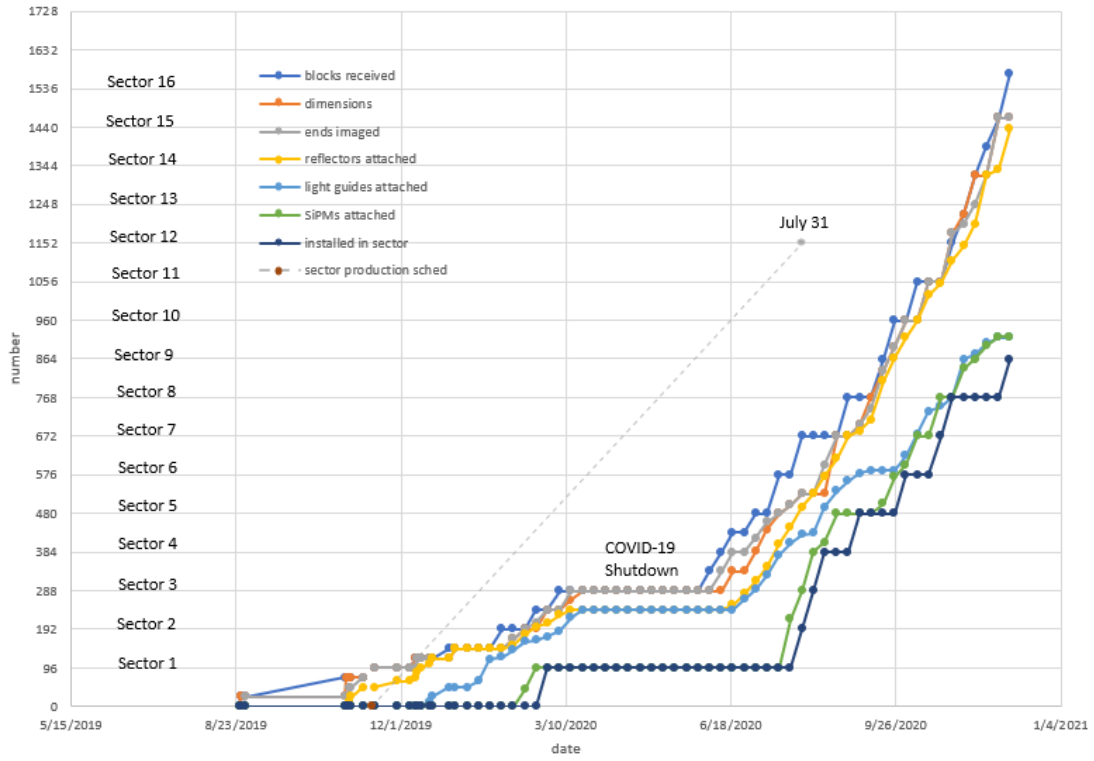


Figure 5. Status of module production at BNL.

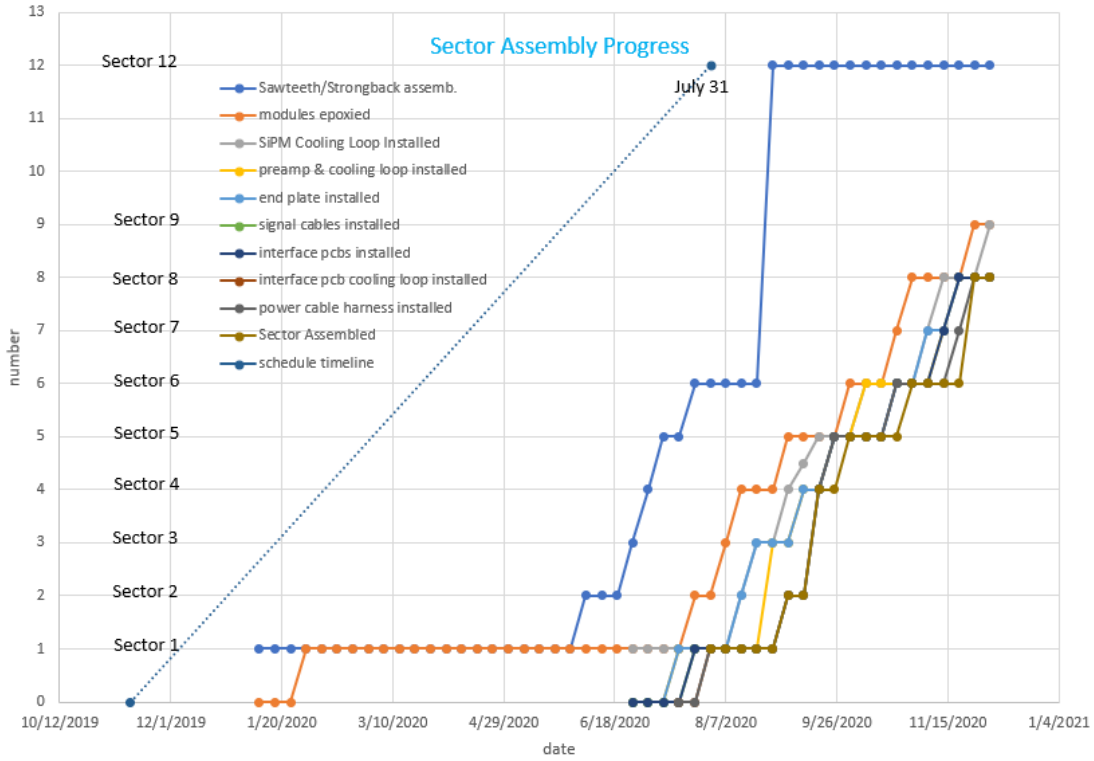


Figure 6. Status of sector assembly at BNL.

Work For the Next 2-3 Months:

Production of blocks for Sectors 13-64 will continue at UIUC. The rate of block production has been shown to reach the target production rate. It will require sufficient labor resources to maintain this rate over the long term.

Production of the high rapidity blocks for Sectors 13-64 will also continue at Fudan. The production rate at Fudan has also reached the full production rate and efforts are under way to be able to maintain this rate.

Work will also continue on module production and sector assembly at BNL. We expect additional deliveries of light guides in December. However, we will continue to run behind schedule until additional labor is available at the end of December. We have hired two additional techs at BNL to work in the EMCal sector factory.

Issues:

We remain limited in our ability to produce modules and assemble sectors due to the lack of technicians. The two new techs have been hired and will start working in the EMCal factory at the end of December. A new graduate student arrived at BNL from the University of Colorado. He will help us with sector testing and is planning to stay at BNL for several months. This will help us with future sector testing and preparations of the sectors for installation and commissioning.

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

WBS 1.4.1 Inner Hadronic Calorimeter

Current Status:

The contract between BNL and Iowa State University (ISU) for the iHCAL sectors has been completed. ISU is in the process of preparing an RFQ that will go out in the next week or so and remain active for 3-4 weeks, after which a vendor will be selected. ISU and Rutgers will place the orders for the iHCAL sector parts and manage their production. The end ring supports have contracted between BNL and an outside vendor.

Work for the Next 2-3 Months:

After the ISU RFQ is complete a vendor will be selected. The delivery schedule from the vendor will be integrated into the sPHENIX assembly plan.

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. More will be known when we have a sector production schedule from the manufacturer.

WBS 1.4.2/3/4 Outer Hadronic Calorimeter

Current Status:

GSU has completed testing of the scintillating tiles required for the outer HCAL, with only 1.4% failing performance testing. It is anticipated that the final shipments of tested tiles from GSU to BNL will occur after the holidays.

Factory operations at BNL are continuing with technician labor and collaborator support from the NY state area. The first six pre-production sectors have been fully assembled, and the first five have been tested and moved to storage. The last pre-production module is finishing testing as of this report and is expected to be completed and moved to storage soon. Nine production sectors have been moved into the assembly area for tile and electronics and cabling installation; all nine have tiles installed and are in various stages of electronics and cable installation. At the present time the limiting factor in sector assembly continues to be the availability of signal cables. Cables from the technicians at NSLS-II have been arriving at the rate of one sector's worth of cables per week; this is anticipated to ramp up shortly to two sector's worth per week. Preamp testing is underway up at both Lehigh University and BNL. We are building up sufficient preamp inventory to support sector assembly. Additional collaboration labor resources have been identified, and ISU has added a new postdoc who resides local to the BNL area to work full-time in the outer HCAL factory. In addition, we hope to be able to bring collaborators onto the BNL site in early 2021 to ramp up oHCAL assembly and testing.

The high-strength endplates, pucks, and pins are expected by the end of December, 2020. The vendor is on track to deliver as scheduled, and we have been in contact with the vendor regarding final pain requirement for the parts.

Work for the Next 2-3 Months:

Over the next six months work on the outer HCAL will continue to focus on production of sector assemblies in the HCAL factory.

Issues:

We continue to be optimistic that we will be able to supplement oHCAL factory labor with graduate students and postdocs from beyond the NY state area in early 2021.

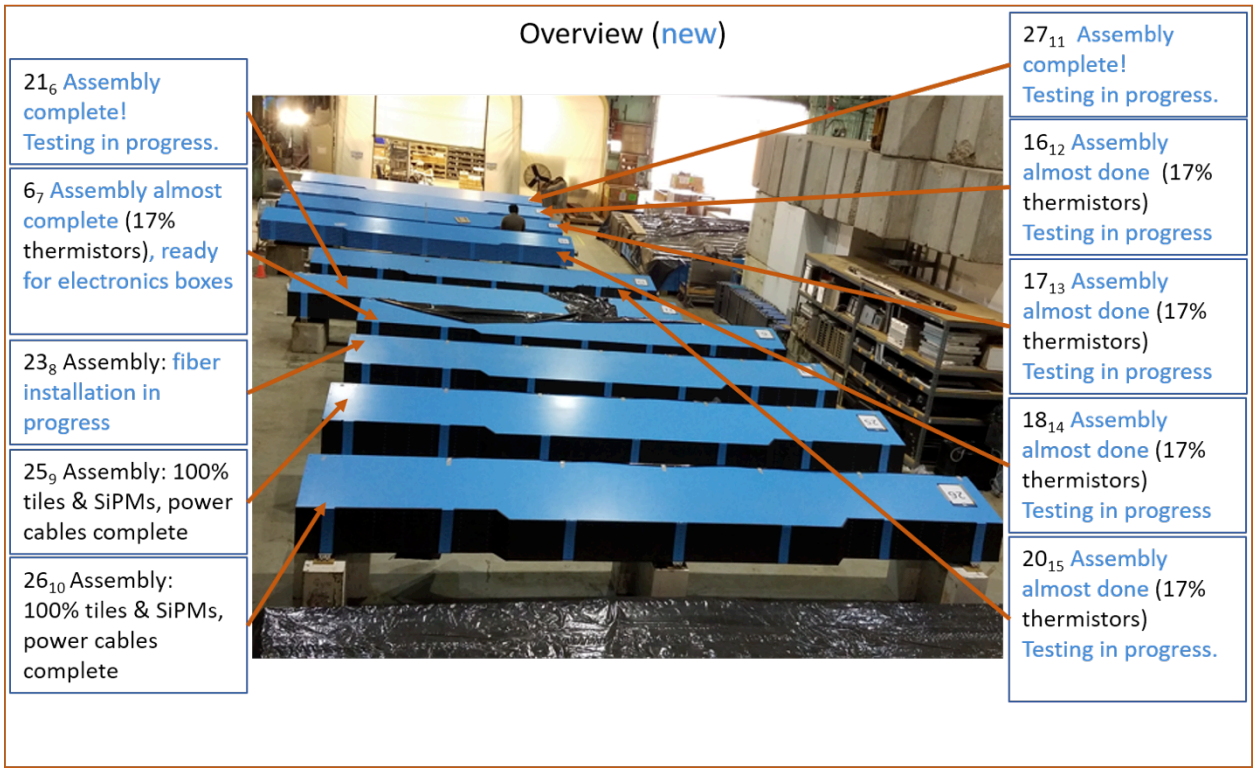


Figure 7: An overview of the status of the ten OHCal sectors currently in the HCal factory at BNL in building 912. A number of these sectors are nearing completion and will be moved to storage soon, with new (empty) sectors taking their place for assembly. Five pre-production sectors are already in storage.

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

Current Status:

Status:

Testing of the EMCal SiPM daughter board continues with a yield of > 99%. The Test of the HCal interface boards has started with approximately 30% of them QA tested and a yield > 98% . HCal LED drive boards QA testing of the boards has continues with a > 99% yield. Assembly of interior cables for the EMCal and HCal continues on schedule. Work continues on finalizing the rack designs and generating the line drawings required to assemble the EMCal and HCal power, slow control and digitizer racks. A preliminary PPR for the exterior signal cables for the EMCal and HCal is scheduled for December of 2020, with the final review scheduled for January of 2021. The crates for the EMCal and HCal racks have been received, with the power modules now scheduled for a February 2021 delivery. Order for the LV power modules has been placed with a delivery date of April 2021. Orders for the low voltage distribution system are being prepared.

The Univ of Colorado group has assembled a test stand and is working to finalize the software and procedures for characterizing the performance of the Calorimeter Digitizer boards as part of the QA process. Univ of Colorado collaborators will also fabricate and assembly all front panels for the Digitizer system. Work is ongoing at Columbia Univ, Nevis Labs to refine the FPGA firmware for the Digitizer system and prepare procurement documentation for long lead-time parts. It is anticipated that orders for long-lead time components will start to be placed in December of 2020.

Work for the next 2-3 months:

Work over the next 3 months will be focused on the continued testing of preproduction sectors and procurement of production electronics. This work includes:

1. Continue assembly of cable assemblies for the remaining 26 HCal modules
2. Test EMCal SiPM boards, HCal Preamps, and HCal LED Driver board.
3. Build the first Digitizer rack with a full crate operational.
4. Work with the Integration and Installation group to finalize cable lengths and rack design
5. Place orders for external cables.
6. Production of low voltage systems.

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:

The purchase order for 20 PCs, a new network switch, and a "first article" file server, called a "BufferBox", had previously been received. The setup of the machines has continued, and we have meanwhile been able to perform tests and confirm the performance benchmarks we had specified.

Figure 8 shows the disk enclosure for the file server, the "Buffer Box", during setup, with its top still off. It holds 102 individual disks with 14TB capacity each, resulting in about 1.5PB raw disk capacity, and 1.2PB usable disk space after RAID setups with hot spares.

Figure 8: A picture of the disk enclosure with 102 14TB disks during setup.

We performed preliminary benchmark tests with the file server. The requirements are a sustained write data rate of about 4-5 GByte/s to disk. The system was set up in a standard way informed by the way the computing center sets up such systems, and we got more than 10 GByte/s. This number may go down slightly after the disk fragmentation increases over time, but we may also still see some increase with a refined tune tailored to our exact use case. For now, this initial result is very encouraging.

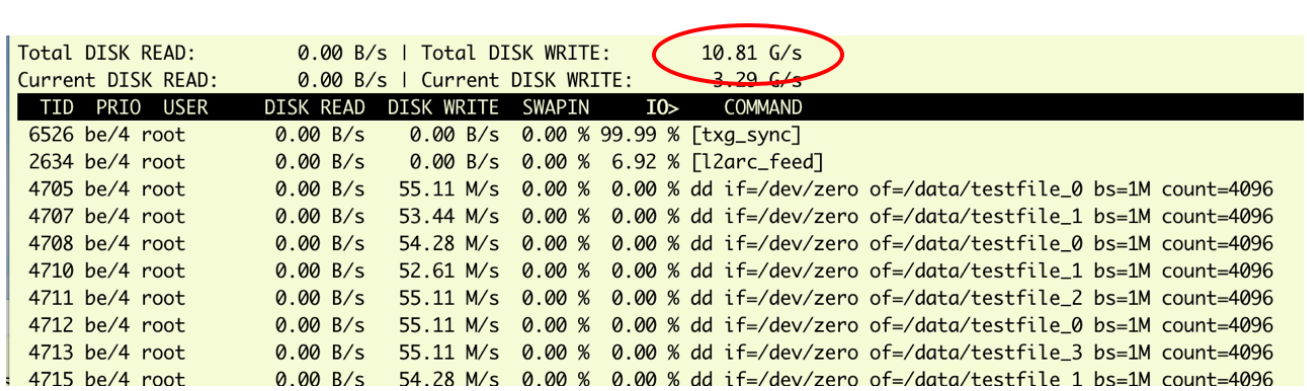


Figure 9: A screenshot of a disk throughput-monitoring program during the performance tests. The circled number of 10.81 GByte/s shows the average rate that exceeds the requirements of 4-5 GByte/s.

The electric work that was performed during that time is close to being finished, and we will be able to power all machines again. We will be able to perform more benchmarks in early December.

The development of more software for the data acquisition back-end has progressed. This will allow us to write data efficiently from the about 60 individual front-end PCs to those file servers (eventually we envision 6 of them).

For the GL1 and Timing System, the design of an add-on board has been completed, and it is under a final review and will be sent out for fabrication. This will make all 14 possible fiber connections available (8 more than the unit has natively) and will serve as both the development platform, as well as the standard triggering unit for all lab test setups and future test beams. Once completed, and after we gain experience with it, the development will shift to a second version with additional features that will then be the unit in use in the actual experiment.

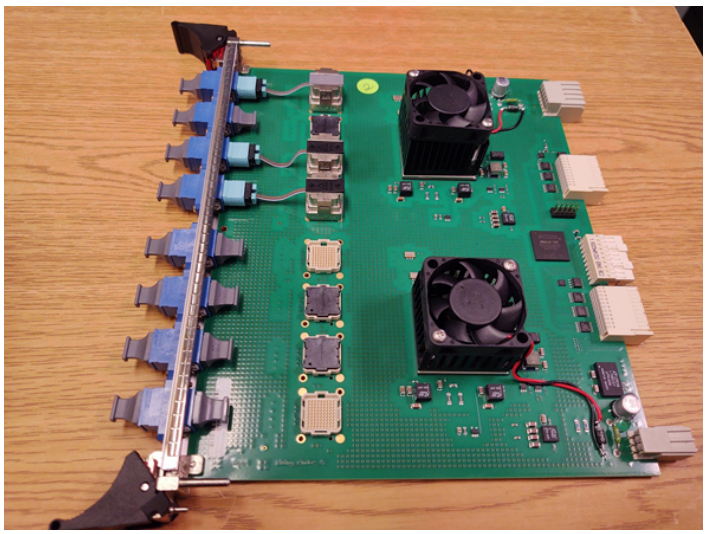


Figure 10: The LL1 board during its thermal management tests. There are different types of cooling fans mounted on the FPGAs.

The tests for the Local-Level 1 trigger board are ongoing. Currently, the requirements for the thermal management are being evaluated so we can design the proper cooling and packaging for the crates that will hold those boards. Figure 10 shows a partially assembled LL1 board with cooling fans mounted on the FPGAs, which are the chips with the highest power consumption and heat dissipation.

Work for the next 2-3 months :

We will perform more benchmarks with the just-installed systems. The Timing System Board will be sent out for fabrication, and work will begin for a second version with additional features. The development of the Local-Level 1 board and firmware will continue.

Issues:

None

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

Current Status:

The test in which we read out multiple MBD Disc/Shaper boards was successful. This test determined the additional jitter from propagating the clock to multiple D/S boards. The tests resulted in an average timing resolution of 40 ps, a little worse than the 30 ps without multiple boards, but still well within the KPP spec of 120 ps. Studies of the MBD in the sPHENIX simulation are on-going, as part of the sPHENIX mock data challenge. These studies will be used to fine-tune the MBD location, the preamp and shaper gain, as well as to determine the effect of pile-up from high rate collisions.

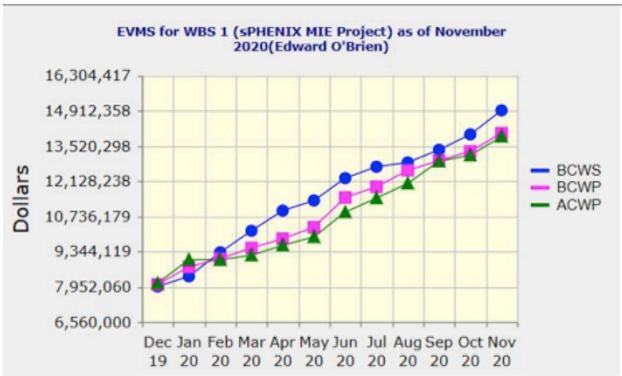
Work for Next 2-3 Months:

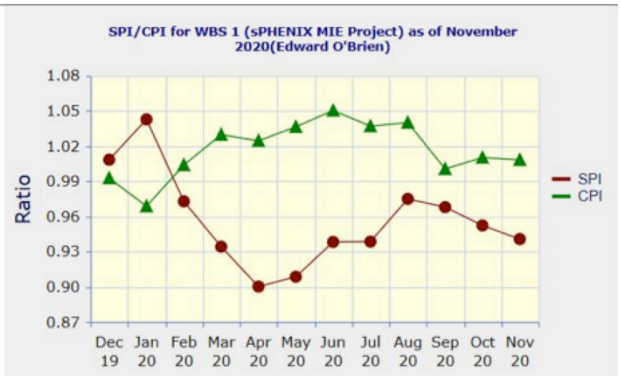
The Columbia University, Nevis Labs lead scientist on the MBD electronics wants to do a couple more tests before we are ready for the final Production Readiness Review. He wants to systematically check the loading on the backplane, which changes as each D/S board is added. He thinks this may contribute to the worse timing resolution in the multi-board test, and it would be good to understand this. He also wants to check the resolution across multiple ADC boards. These tests will be performed in late November, which may push back the final Production Readiness Review into January, about a month behind schedule, but still well within available float. The L2 Manager for the MBD continues to meet weekly with grad students from Howard and Florida A&M Univ to train them on the skill set required for testing and operating the MBD.

Issues:

None

SPI and CPI Trends





BAC: $24,309,836 **EAC:** $24,199,225 **VAC:** $110,611

Cumulative SPI	Cumulative CPI
0.94	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)	$14,915,485
Cumulative BCWP (Performed)	$14,019,300
Cumulative ACWP (Actual)	$13,885,041

November 2020 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	1,790,636	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

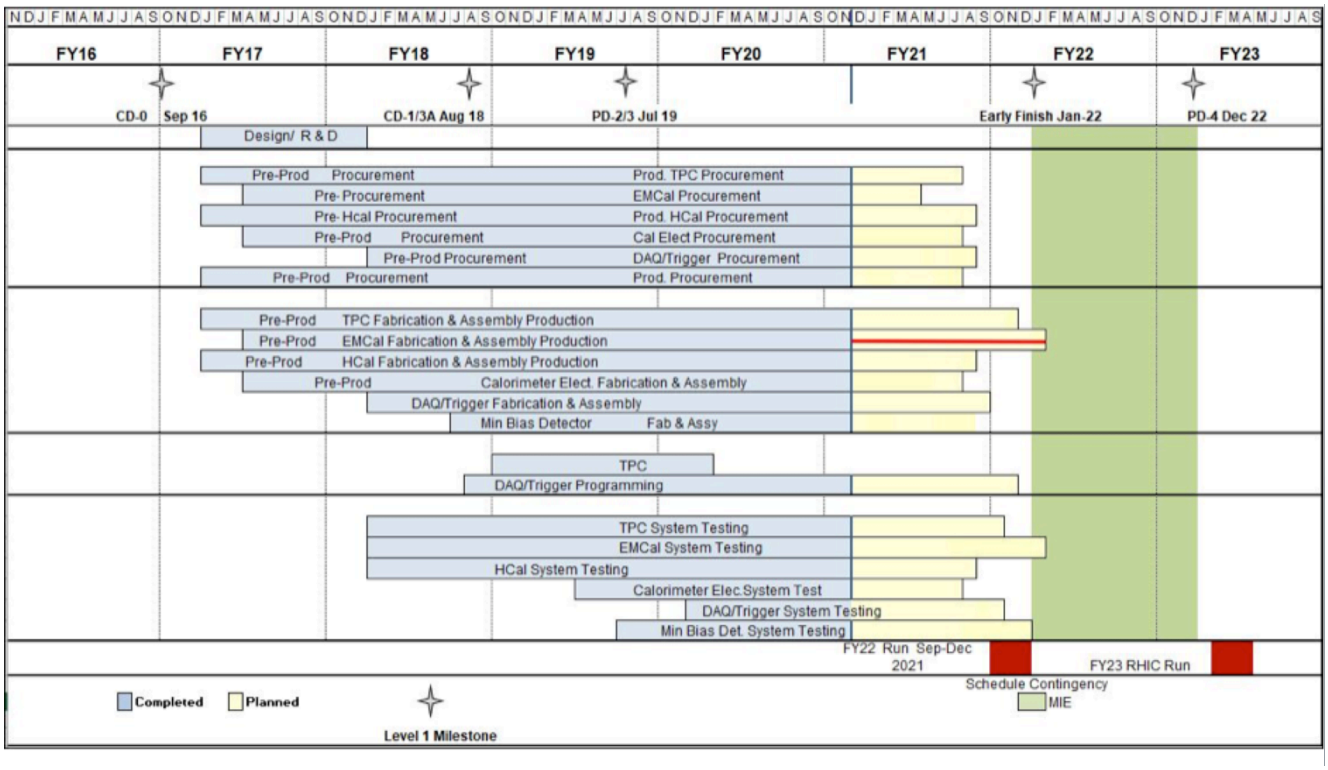
L1 & L2 Milestones

#	WBS	Milestone Name	Target Milestone Date	Forecast	Actual Finish	Variance (in work days)
1	01.01.01	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	01.05.01	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	01.06.02.03	Trigger LL1 Preproduction complete	26-Feb-21	3-May-21		-47
13	01.05.02.02	EMCal SiPM Boards Production Complete	31-Mar-21	4-Mar-21		18
14	01.04.04.02	First Outer HCAL Sector and Splice Plates Ready to Install	30-Apr-21	14-Jan-21		73
15	01.04.01	Inner HCAL Support Structure Ready for Installation	30-Apr-21	29-Jun-21		-42
16	01.02.01.06	GEM Production Complete	31-May-21	15-Mar-21		54
17	01.03.01.03.01	EMCal Scintillating Fiber Acquisition Complete	31-May-21	1-Mar-21		64
18	01.02.06.03	TPC DAM Felix 2.0 Production Complete	28-Jun-21	20-Sep-21		-59
19	01.05.02.04	HCal Electronics Complete: Production	30-Jun-21	8-Feb-21		99
20	01.02.05.04	TPC FEE Production Complete	16-Aug-21	27-Aug-21		-10
21	01.05.02.02	EMCal Electronics Complete	16-Aug-21	10-Aug-21		3
22	01.05.03.02	Calorimeter Electronics Complete	20-Sep-21	10-Aug-21		27
23	1.07	MinBias Detector Ready to Install	30-Sep-21	23-Dec-21		-57
24	01.06.03.03	GL1 Ready to Operate	30-Sep-21	4-Jan-22		-63
25	01.01.01	Early Project Completion	29-Oct-21	12-Jan-22		-48
26	01.02.01.08	TPC Ready to Install (Assembly Complete)	29-Oct-21	16-Dec-21		-32
27	01.02.06.03	TPC DAM Production Complete	29-Oct-21	3-Dec-21		-23
28	01.04.04.02	Last Outer HCAL Sector Ready to Install	29-Oct-21	22-Sep-21		25
29	01.06.01.03	DAQ Production: DAQ Ready for Operation	29-Oct-21	14-Dec-21		-30
30	01.06.02.04	LL1 Trigger Production Complete	29-Oct-21	24-Nov-21		-18
31	01.06.02.04	LL1 Ready to Operate	29-Oct-21	24-Nov-21		-18
32	01.03.02.03.03	EMCal Ready to Install	29-Nov-21	11-Jan-22		-30
33	01.01.01	Approve Project Closeout PD-4	30-Dec-22	29-Dec-22*		0

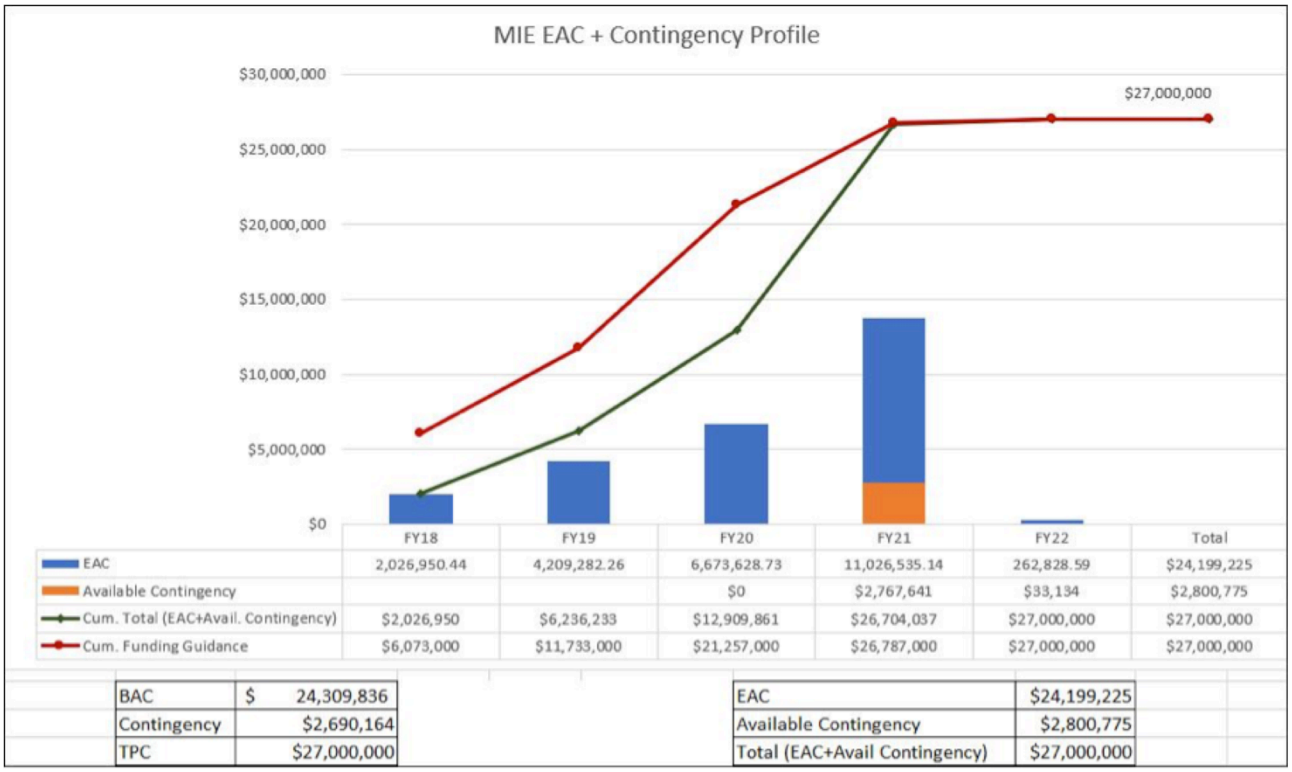
sPHENIX Budget Profile:

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	11,026,535.14	262,828.59	$24,199,225
Available Contingency			$0	$2,767,641	$33,134	$2,800,775
Cum. Total (EAC+Avail. Contingency)	$2,026,950	$6,236,233	$12,909,861	$26,704,037	$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	$ 24,309,836
Contingency	$2,690,164
TPC	$27,000,000

EAC	$24,199,225
Available Contingency	$2,800,775
Total (EAC+Avail Contingency)	$27,000,000

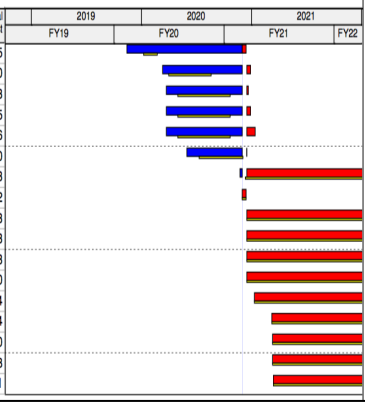
Baseline/Contingency Log

Date	PCR ID	PCR Title	WBS affected	sPHENIX MIE Baseline Cost	PCR Change	Contingency	Total Project Cost
9/20/2019	Approved MIE	Setting up Baseline	all	$22,169,490		$4,830,510	$27,000,000
9/24/2019	007A	Hcal Scin Tiles placed Contract delivery schedule	1.04 HCal	$22,132,844	($36,646)	$4,867,156	$27,000,000
1/31/2020	008A	OHCal Sci.Tiles delivery schedule update	1.04 HCal	$22,132,943	$100	$4,867,056	$27,000,000
2/27/2020	009A	Extending the lead time for IHCal Support Rings	1.04 HCal	$22,132,943	$0	$4,867,056	$27,000,000
3/31/2020	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
4/28/2020	013A	EMCal Block assembly contract details schedule update	1.03 EMCal	$22,195,549	$ 1,736	$4,804,451	$27,000,000
5/27/2020	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
6/19/2020	105A	COVID-19 Schedule Adjustments	All	$22,198,743	$ 21,780	$4,801,257	$27,000,000
10/30/2020	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

Critical Path

POM02 sPHENIX WBS 1.x, 2.x November 2020 Archive — IPD - MIE Critical

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
S193600	Build mechanical enclosure for Prepro Sectors 1-12	271	0	13-Nov-19 A	14-Dec-20	09-Jan-20	21-Feb-20	-204	336	0	38,345	38,345
S193900	Install modules in Prepro Sectors 1-12	202	0	11-Mar-20 A	29-Dec-20	01-Apr-20	20-Aug-20	-87	775	0	95,670	95,670
S194200	Test and Review Preproduction Sectors 1-12 with LEDs & cosmic rays	188	0	24-Mar-20 A	21-Dec-20	01-May-20	21-Oct-20	-40	2086	0	67,343	67,343
S194000	Install readout electronics on Prepro Sectors 1-12	193	0	24-Mar-20 A	29-Dec-20	01-May-20	21-Oct-20	-45	775	0	96,005	96,005
S194100	Install cables and cooling system on Prepro Sectors 1-12	200	0	25-Mar-20 A	11-Jan-21	01-May-20	21-Oct-20	-53	1319	0	178,526	178,526
S187300	Procure light guides for modules in Sectors 13-64 - Contract/PO Leadti	135	0	01-Jun-20 A	15-Dec-20	09-Jul-20	02-Dec-20	-8	0	0	0	0
S187800	Install reflectors on final blocks Labor	278	0	23-Nov-20 A	05-Jan-22	11-Dec-20	05-Jan-22	0	1384	0	179,723	179,723
S224100	Assemble EMCal External Power Cables: Sectors 1-12	10	0	01-Dec-20	14-Dec-20	01-Dec-20	14-Dec-20	0	78	0	9,462	9,462
S187600	Install light guides on final blocks Labor	266	0	15-Dec-20	07-Jan-22	15-Dec-20	07-Jan-22	0	1384	0	179,763	179,763
S188200	Glue final blocks together into modules	264	0	16-Dec-20	06-Jan-22	16-Dec-20	06-Jan-22	0	1384	0	179,753	179,753
S188000	Install SiPMs daughterboards on final blocks Labor	266	0	16-Dec-20	10-Jan-22	16-Dec-20	10-Jan-22	0	1384	0	179,783	179,783
S188100	Install SiPMs daughterboards on final blocks M&S	266	0	16-Dec-20	10-Jan-22	16-Dec-20	10-Jan-22	0	0	300	350	350
S196500	Install modules in final sectors	248	0	11-Jan-21	06-Jan-22	11-Jan-21	06-Jan-22	0	1845	0	234,444	234,444
S196700	Install readout electronics on final sectors	209	0	10-Mar-21	07-Jan-22	10-Mar-21	07-Jan-22	0	1845	0	234,814	234,814
S196800	Install cables & cooling system on final sectors	208	0	11-Mar-21	07-Jan-22	11-Mar-21	07-Jan-22	0	3573	0	499,390	499,390
S196900	Test final sectors with LEDs & cosmic rays	208	0	12-Mar-21	10-Jan-22	12-Mar-21	10-Jan-22	0	5532	0	125,568	125,568
S197000	Repair or rework any sectors as required	208	0	15-Mar-21	11-Jan-22	15-Mar-21	11-Jan-22	0	3921	0	251,931	251,931



Variance Analysis

WBS 1.02A Reporting Period: November 2020

TPC

	BCWS	BCWP	ACWP	SV in $	SV in %	CV in $	CV in %	SPI	CPI
Current:	47,100	196,407	308,613	149,307	317%	-112,206	-57%	4.17	0.64
Cumulative:	2,646,885	2,358,027	2,135,898	-288,857	-11%	222,129	9%	0.89	1.10
	BAC								

At Complete: 4,702,483

Threshold(s) Exceeded: Cumulative Schedule

Explanation of Variance/Description of Problem:
WBS 1.2.1.6 – GEM acquisition – The GEM start of production was delayed by CERN COVID shutdown leading to a -$47k SV. WBS 1.2.2.3 – TPC GEM Modules R1, R2, R3 – Procure TPC Module Parts – The R1 Pad Planes had to be changed to avoid amplifier saturation in the inner 10 cm. The R2 & R3 pad planes are fully delivered. This leads to a -$50K of SV. WBS 1.2.5.4 – FEE Components Acquisition. The FEE cards had to be rebid due to a failed first bid. This leads to a SV of -$188k. WBS 1.2.7.1 TPC Support System - Laser – manufacture delays experienced in the first magnetic-field-tolerant laser for sPHENIX leads to -$223K of SV. WBS 1.2.7.2 TPC Support System – Gas System – Gas system components order delayed with -$40k of SV. WBS 1.2.7.3 TPC Support System – Cooling System – Bench test required for validation delayed due to COVID. This leads to -$63k of SV.

Impact:
WBS 1.2.1.6 – GEM acquisition – impact none. GEMs have 92 days float. WBS 1.2.2.3 – TPC GEM Modules R1,R2,R3 – Procure TPC Module Parts – impact none. Pad plane has 47 days float. WBS 1.2.5.4 – FEE Components Acquisition. Impact none, 30 days of float. WBS 1.2.7.1 TPC Support System - Laser impact none. Optics has 103 days float. WBS 1.2.7 TPC Support System – Gas System – Impact none. The system has 80 days float; impact none. WBS 1.2.7 TPC Support System – Cooling System – Impact none. The system has 31 days float; impact none.

Corrective Action:
WBS 1.2.1.6 – GEM acquisition – none. WBS 1.2.2-4.3 – TPC GEM Modules R1,R2,R3 –R1 design in engineering review. WBS 1.2.5.4 – FEE Components Acquisition – Improve testing plan for increased parallelization to recoup time after first article deliveries. WBS 1.2.7.1 TPC Support System - Laser – none. First article laser expected for test in December. WBS 1.2.7 TPC Support System – Gas System – none. WBS 1.2.7 TPC Support System – Cooling System – Final design review scheduled in December. Parts orders readied.

Prepared:	Prepared By:	Approved:	Approved By:
12/16/2020	Irina Sourikova [22419]	12/18/2020	Edward O'Brien [18368]

WBS 1.04A **Reporting Period:** November 2020

HCal

	BCWS	BCWP	ACWP	SV in $	SV in %	CV in $	CV in %	SPI	CPI
Current:	324,579	119,984	838	-204,595	-63%	119,147	99%	0.37	143.25
Cumulative:	2,813,010	2,513,268	2,489,745	-299,742	-11%	23,523	1%	0.89	1.01
	BAC								

At Complete: 4,160,785

Threshold(s) Exceeded: Cumulative Schedule

Explanation of Variance/Description of Problem:
WBS 1.4.2 – OHCal Sector Mechanics (S205100) – the splice plates delivery from the manufacturer is behind schedule, with negative SV =-$303K. This dominates the HCAL schedule variance.

Impact:
WBS 1.4.2 OHCal Sector Mechanics (S205100) – impact none, the splice plates are needed in June 2021 and thus have 120 days float.

Corrective Action:
WBS 1.4.2 OHCal Sector Mechanics (S205100) – the splice plates are under fabrication at a vendor. The vendor has updated the delivery schedule to the end of December 2020. This is still well in advance of when they are required for outer HCAL assembly and no corrective action is required.

Prepared:	**Prepared By:**	**Approved:**	**Approved By:**
12/16/2020	John Lajoie [L5823]	12/18/2020	Edward O'Brien [18368]

WBS 1.05A **Reporting Period:** November 2020

Calorimeter Electronics

	BCWS	**BCWP**	**ACWP**	**SV in $**	**SV in %**	**CV in $**	**CV in %**	**SPI**	**CPI**
Current:	434,864	39,300	103,428	-395,564	-91%	-64,128	-163%	0.09	0.38
Cumulative:	3,079,336	2,661,930	2,702,840	-417,406	-14%	-40,910	-2%	0.86	0.98
	BAC								
At Complete:	6,290,621								

Threshold(s) Exceeded: Cumulative Schedule

Explanation of Variance/Description of Problem:
WBS 1.5.2 Calorimeter Electronics – EMCal low voltage system has not been delivered due to long lead time on parts. This leads to -$36.5K of SV. WBS 1.5.2 Calorimeter Electronics – EMCal bias power system has not been delivered due to long lead time on parts. This leads to -$35K of SV. WBS 1.5.2 Calorimeter Electronics – EMCal SiPM boards order has not been completed. This leads to -24K of SV. WBS 1.5.2 Calorimeter Electronics –EMCal Interface boards have not been delivered from the vendor. This leads to -$196K of SV. WBS 1.5.2 Calorimeter Electronics – Calorimeter Controller boards were purchased in advance and tested in advance schedule. This leans

to +$94K of SV. WBS 1.5.2 Calorimeter Electronics – EMCal interior signal, and power cables order has not been completed delivered by vendors. This leads to -$288K of SV. WBS 1.5.2 Calorimeter Electronics – Calorimeter test pulse boards have not been ordered. This leads to -$8K of SV. WBS 1.5.2 Calorimeter Electronics – EMCal Crates for controllers have not been ordered. This leads to -$5K of SV. WBS 1.5.2 Calorimeter Electronics – HCal SiPM daughter boards were assembled with the preproduction order ahead of schedule. This leads to +$111K of SV. WBS 1.5.2 Calorimeter Electronics - HCal interior power and signal cables were purchased ahead of schedule. This leads to +$94K of SV. WBS 1.5.2 Calorimeter Electronics – HCal external power and signal cables, low voltage system and bias systems have not been delivered. This leads to -$102K of SV.

Impact:
WBS 1.5.2 Calorimeter Electronics – EMCal low voltage system- None. The power supplies have been ordered with a delivery date of April 2021. The low voltage crates have already been received and can be used to start rack assembly. WBS 1.5.2 Calorimeter Electronics – EMCal bias power system- None. The bias system has been ordered and the crates delivered. The bias modules are scheduled for an Feb 2021 delivery time. WBS 1.5.2 Calorimeter Electronics – EMCal SiPM boards- None. The order for the second half of the boards will be placed in December, with an estimated completion date of February 2021. There are sufficient daughter boards to maintain sector assembly. WBS 1.5.2 Calorimeter Electronics –EMCal Interface boards- None. A partial delivery is scheduled for December of 2020, with the completion of the order scheduled for January 2021. Sufficient interface boards are available to keep up the EMCal sector assembly. WBS 1.5.2 Calorimeter Electronics – EMCal controller boards- None. This task is complete ahead of schedule. WBS 1.5.2 Calorimeter Electronics – EMCal interior signal, and power cables- None. All power cables have been delivered and partial deliveries of signal cables have been received to allow assembly of EMCal sectors to continue on schedule. WBS 1.5.2 Calorimeter Electronics – Calorimeter test pulse boards- None. There are sufficient boards to perform initial EMCal and HCal testing. WBS 1.5.2 Calorimeter Electronics – EMCal Crates for controllers have not been ordered- None. Crate order will be placed in early 2021 and delivered in time for installation into the racks. WBS 1.5.2 Calorimeter Electronics – HCal SiPM daughter boards- None. This task is complete ahead of schedule. WBS 1.5.2 Calorimeter Electronics – HCal interior power and signal cables, low voltage system- None. The cables have been delivered and are available for installation. The low voltage and bias systems are ordered with an early 2021 delivery date. Rack assembly can start before the scheduled arrival.

Corrective Action:
WBS 1.5.2 Calorimeter Electronics – EMCal low voltage system: The order has been placed and the vendor has a strong track record of delivering on time. Will continue to follow up with vendor on delivery schedule to monitor any changes in schedule. WBS 1.5.2 Calorimeter Electronics – EMCal bias power system: The order has been placed and the vendor has a strong track record of delivering on time. Will continue to follow up with vendor on delivery schedule to monitor any changes in schedule. WBS 1.5.2 Calorimeter Electronics – EMCal SiPM boards: Work BNL procurement to see that the order is placed in a timely manner using the vendor that produced the first half of the boards. Vendor delivered the first half of the number of boards required ahead of schedule. Sufficient boards have been received to maintain EMCal sector assembly. WBS 1.5.2 Calorimeter Electronics –EMCal Interface boards: A partial delivery is scheduled for December of 2020, with the completion of the order scheduled for January 2021. Sufficient interface boards are available to keep up the EMCal sector assembly. WBS 1.5.2 Calorimeter Electronics – EMCal controller boards: This task is complete ahead of schedule. WBS 1.5.2 Calorimeter Electronics – EMCal interior signal, and power cables: All interior power cables have been delivered. Signal cables are being delivered on a regular schedule by the vendor with fully delivery scheduled in February. Sufficient cables have been delivered to meet the EMCal sector assembly schedule. WBS 1.5.2 Calorimeter Electronics – Calorimeter test pulse

boards: These boards will be ordered in early 2021 and are not needed until the digitizer racks are assembled. WBS 1.5.2 Calorimeter Electronics – EMCal Crates for controllers: These crates are stock items and will be ordered in early 2021 with delivery scheduled before rack assembly starts in mid-2021. WBS 1.5.2 Calorimeter Electronics – HCal SiPM daughter boards: This task is complete ahead of schedule. WBS 1.5.2 Calorimeter Electronics – HCal interior power and signal cables, low voltage system: The power cables and signal cables have been delivered and are available for installation into HCal sectors. The low voltage and bias systems are ordered with an early 2021 delivery date. The crates for them have been received allowing for assembly of the HCal power racks.

Prepared:	**Prepared By:**	**Approved:**	**Approved By:**
12/16/2020	Irina Sourikova [22419]	12/18/2020	Edward O'Brien [18368]

WBS 1.06A **Reporting Period:** November 2020

DAQ & Trigger

	BCWS	**BCWP**	**ACWP**	**SV in $**	**SV in %**	**CV in $**	**CV in %**	**SPI**	**CPI**
Current:	0	186,807	297,743	186,807	0%	-110,936	-59%	0.00	0.63
Cumulative:	242,014	525,778	564,510	283,764	117%	-38,732	-7%	2.17	0.93
	BAC								
At Complete:	1,245,090								

Threshold(s) Exceeded: Cumulative Schedule

Explanation of Variance/Description of Problem:
WBS 01.06.01.03 1) "Procurement of SEBs and ATPs" - the procurement happened ahead of schedule, resulting in a combined SV and CV of $161,437. 2) "JSEB Slow control Computers" - we may have found an easier way to accomplish the slow controls, and decided to delay the procurement until we perform tests to see if this is a viable solution, this results in a SV of -$19,181. 3) As with 1), we procured 1 of 6 "Buffer Boxes" ahead of schedule to get a head-start with setup and experience in tuning, resulting in a SV and CV of $41,513. 4) We also procured the main network switch ahead of schedule, resulting in a SV and CV of $99,994. 5) That switch, originally budgeted for $99,994, was procured for about half the price for the same or better performance, resulting in the overall CV of -$48,517.

Impact:
None. The procurements of SEBs and ATPS, the "first article" bufferbox, and the network switch allows us to partially mitigate the impact of COVID-19 restrictions by performing tasks that can be done safely now, such as the hardware setup. The configuration and testing can largely be done remotely. The deferral of the slow controls computers procurement might lead to an easier way to accomplish this, but also frees up time to perform the tasks that can more easily be done during the COVID-19 restrictions. The overall CV of -$48,517 are true cost savings for

the same or better performance.

Corrective Action:
None

Prepared:	**Prepared By:**	**Approved:**	**Approved By:**
12/16/2020	Irina Sourikova [22419]	12/18/2020	Edward O'Brien [18368]