

## sPHENIX Project Status Report – January 2021

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 January 31, 2021

Current PD:	<b>2/3</b>	Date of Current CD/PD approval	September 2019	
Next PD:	<b>4</b>	Forecast approval:	<b>1QFY23</b>	Baseline: <b>1QFY23</b>
% Complete:	<b>61.1%</b>	Planned:	<b>77.4%</b>	
ETC:	<b>\$9.57M</b>	TPC or Cost Range:	<b>\$27.0M</b>	
Contingency:	<b>22.0%</b> on ETC	Float to PD-4 in months:	<b>11.0</b>	
Cumulative CPI:	<b>1.01</b>	Cumulative SPI:	<b>0.79</b>	

### 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 continuing to implement a 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 will reduce after February as the COVID peak continues to decrease in the US, delayed vendor deliveries start to arrive at BNL and our labor increases begin to mitigate the effects the pandemic is having on the schedule. We expect the SPI to slowly improve over the next few months due to these factors. The project cost performance remains excellent. We will continue to hold Final Design Reviews and Production Readiness Reviews as detector components move from prototyping and design to production.

Work of the TPC outer field cage will continue. The aluminum stripes will be evaporated onto the central membrane petals. The field cage pieces will begin assembly into the final full unit. The full production order of 700 TPC FEE boards are pending a successful preproduction round with the vendor and a slice test (system test) of one sector's worth of TPC Fee boards. Orders for the assembly of the FELIX cards will be placed.

Production of blocks for Sectors 13-64 will continue at UIUC. The rate of block production increased after the Christmas holiday but is currently limited from reaching its full capacity due to the need for a second full time machinist in the factory. UIUC is planning to hire an additional machinist to address this need. Production of the high rapidity blocks for Sectors 13-64 will also continue at Fudan. Module production and sector assembly will continue at BNL. There are sufficient parts to complete sector production at full speed until early March. After that there will be a shortage of preamps until April. The shortage is due to a long lead-time in a particular component on the preamp board. There is a work around to allow EMCAL sector assembly to continue while the EMCAL Sector factory waits for the preamps to arrive.

The vendor for the Inner HCal frame will begin machining the individual sectors within the next two months. ISU and Rutgers will continue to coordinate with the IHCAL frame vendor to ensure good communication and adherence to the production schedule. Over the next several months work on the outer HCal will center on completing production sector assemblies in the HCal factory. We expect OHCAL sectors to be completed at a rate of over 1/week for the next few months. We expect the joining plates, pucks and pins needed to assemble the OHCAL sectors into a barrel to arrive from the vendor.

Work on the calorimeter electronics over the next 3 months will be focused on the continued testing of sectors and procurement of production electronics. We will continue assembly of cable assemblies for the remaining 13 HCal modules, continue testing of EMCAL SiPM boards and HCal Preamps, design and build the HCal power racks, build the first Cal Digitizer rack with a fully operational crate, place orders for external EMCAL and HCal cables, and manage the production of low voltage systems.

The DAQ/Trigger group will work on the further implementation of our run control software. The development of the Local-Level 1 board and firmware will continue.

The Min Bias detector group is preparing for the Final Design Review of the D/S electronics, and following that will prepare the procurement and production-testing plan. A BNL scientist will continue to train university students in how to test and eventually operate the MBD.

### 3. STATUS HIGHLIGHTS

Production components for the sPHENIX detector continue to arrive. 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. All long lead procurement items were complete in January with the exception of one item which was 95% delivered (**as of Feb 19, 2021 the LLP items were 100% complete**).

The early completion date for sPHENIX is unchanged for January. It remains the end of January 2022. Eleven months of schedule contingency to the PD-4 date remains. The project cost performance remains excellent. EVMS processing was completed for January. Cobra and P6 monthly reports uploaded to IPD. The variance reports were approved. A PCR was approved in January to move the Early Project Completion date to January 31, 2022 and add technical labor for WBS 1.2 – Time Projection Chamber. The project is 61.1% complete in January with a 22% contingency on the ETC. The project is 82.9% costed and committed.

A second order of GEM foils for the TPC arrived from CERN and has been distributed to the GEM factories at Vanderbilt, WSU, WIS and Temple Univ. Alignment of the TPC outer field cage stripes is 4/5 complete at SBU. Magnetic field tests on the FEE and the line lasers were successful. The FEE worked flawlessly. The line lasers required tuning of the maximum pump current as expected, and then produced the desired output. All mechanics of the on-board cooling system are ordered and in construction. Delivery of the pre-production FEE cards is over 95% complete, testing has started on the preproduction electronics boards.

EMCAL Block production at UIUC made excellent progress in January. As of January 18, blocks for 20 sectors have been shipped to BNL. Block yield is ~ 98%. Work on module production and sector assembly

continues at BNL. The addition of two more techs has greatly helped increase productivity. The earlier delivery problem with the light guides has now been resolved and they are arriving at a rate sufficient to keep the module/sector production on schedule. Ten EMCAL sectors have been completed and tested at BNL. There is currently a delivery problem with the preamp boards related to a long lead-time electronic component. We have enough preamps to complete EMCAL sector assembly and testing through sector 15. The factory engineers and technicians have devised a work around that will allow sector production to continue while waiting for the preamps deliveries expected in April.

ISU has contracted with a vendor to provide the iHCAL mechanical sectors. Raw material has been ordered and a delivery schedule has been provided by the vendor and is being integrated into P6. First article inspection is expected by 5/21/2021 with delivery of the first eight sectors shortly thereafter. Factory operations at BNL are continuing with technician labor and collaborator support from collaborating institutions (Baruch, UC Boulder, Rutgers, Lehigh, Ohio, and ISU). The first six pre-production sectors have been fully assembled and tested, along with twelve production sectors, and all eighteen have been tested and moved to storage. Ten OHCAL production sectors have been moved into the assembly area for tile and electronics and cabling installation and are in various stages of assembly. A partial shipment consisting of the high-strength endplates, two of the splice plates, and a sample of the pucks and pins have been delivered to BNL. Delivery of the remainder of the order has been delayed to the end of February 2021 due to a COVID impact on the schedule at the vendor.

Testing of the EMCAL SiPM daughter boards continues with a failure rate of less than 1%. Testing of HCal preamps continues with the assistance of Lehigh University and Iowa State University with a yield greater than 95%. BNL technicians continue to provide interior signal cable assemblies for the OHCAL factory. The vendor providing the EMCAL interior signal cables has continued to deliver cable assemblies on schedule. The first EMCAL power rack was delivered to the EMCAL group and will be used for burn-in testing of the EMCAL sectors. The parts orders for the full calorimeter digitizer system are being submitted to the Columbia University purchasing department. The Colorado group has completed the assembly of a calorimeter digitizer test stand at Colorado University, and is preparing to receive the assembled boards for the 7-crate production for installation of front panels and final testing.

The sPHENIX "Run Control" was exercised by having 15 individual instances of readout processes started and controlled on 15 PCs, all of which sent their data to the buffer box. An earlier test yielded 25Gbit/s throughput using the buffer box as a NFS server, which is standard operation mode but not the most efficient. We have meanwhile implemented a dedicated data transfer protocol, called the "Super-Fast Server" (sfs), and using this server we were able to more than double the data transfer from 25Gbit/s to 55Gbit/s. The design of an add-on board has been completed for the GL1 and Timing system.

After completing timing and performance tests for the Min Bias Detector Discriminator/Shaper board, we held a FDR/PRR. The MBD D/S preproduction board has passed its performance tests.

## **WBS 1.1 Project Management (L2 Manager: Irina Sourikova)**

### **Current Status:**

- SPI is 0.79, CPI is 1.01

**Highlights:**

- PCR approved to move the Early Project Completion date to January 2022 and add technical labor for WBS 1.2 – Time Projection Chamber.
- FDR/PRR for EMCal/HCal Signal Cable complete.
- EVMS processing complete.
- Cobra and P6 monthly reports uploaded to IPD.
- Variance reports approved.

**Plans for the next 2-3 month:**

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

**Issues:**

- The COVID spike in the US from Nov-Feb has had an impact on project schedule performance. The Negative Schedule Variance increased in January partly due to late deliveries from vendors and partly due to a decrease in existing positive schedule variance.

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

GEMS from the second major shipment arrived on time and are in the hands of the university factories.

The R1 pad plane PO is completed and out the door.

Magnetic field tests on the FEE and the line lasers were initiated successfully. The FEE worked flawlessly. The line lasers required tuning of the maximum pump current (a known and expected effect) and then produced the desired output. Longer terms tests are still ongoing, but all signs indicate success presently.

Orders continue to go out for the TPC support systems including cooling, gas, and lasers. All mechanics of the on-board cooling system are ordered and in construction.

Alignment of the TPC outer field cage stripes is 4/5 completed.

Delivery of the pre-production FEE cards is accomplished and verification is ongoing.

**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. The full production order of 700 TPC FEE boards are pending a successful preproduction round with the vendor and a slice test (system test) of 1 sector's worth of TPC Fee boards.

**Issues:**

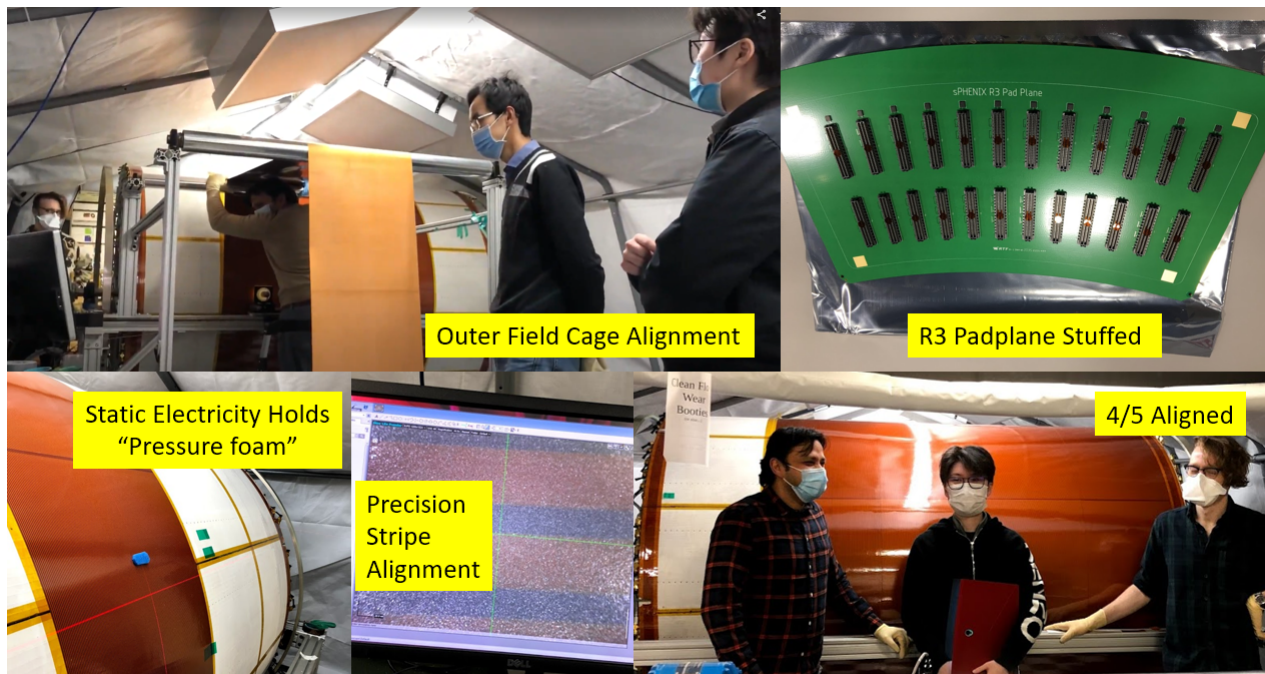
A full impact of the use of JACK cards for scrubbing to minimize single event-upsets is required. The cost of Felix+JACK and Felix+Felix is almost the same, but the impact stretches beyond the TPC into the DAQ and must be fully vetted before a decision can be made on which technical solution to choose.

**COVID:**

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. None of these have yet put the TPC on or near the critical path.

The central tube for the TPC assembly cart was to have been completed in December 2020 in the BNL shops, but the shop decided to send this out for commercial manufacture, incurring additional cost to keep our schedule.

At the time of this writing (Feb), much of the SBU crew is on COVID-quarantine. It seems as though the one positive test from one lab member was likely a false positive as subsequent tests have come up negative. Nonetheless, persons having contact with the positively infected individual are on a 10-day quarantine by University and New York State rules. February productivity will be affected.

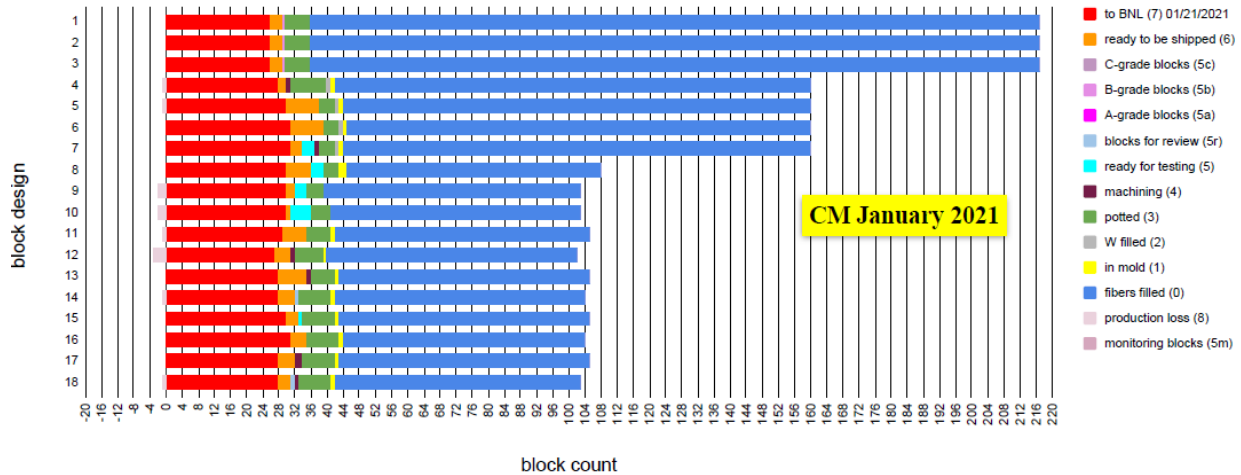


**Figure 1:** Clockwise from upper left: Alignment of the Outer Field Cage ongoing at SBU. An R3 pad plane stuffed with connectors. Outer field cage alignment 80% complete. Close up of the stripe alignment. Outer field cage with pressure foam.

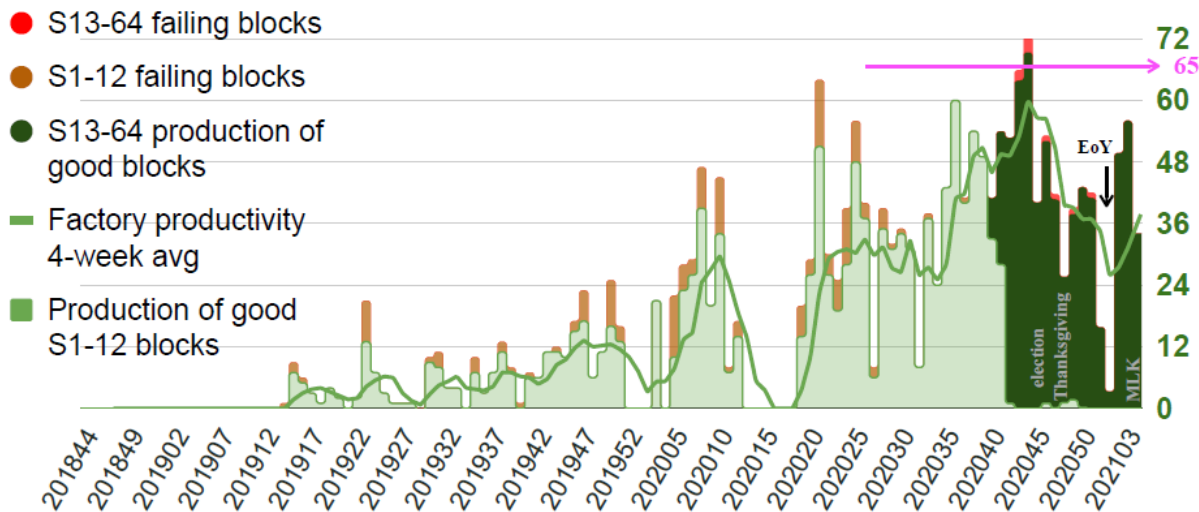
**WBS 1.3 Electromagnetic Calorimeter (L2 Manager: Craig Woody, BNL)**

**Current Status:**

Block production at UIUC made excellent progress in January. Figure 2 shows the status of the blocks for Sectors 13-64 at the time of the January sPHENIX Collaboration Meeting. As of January 21<sup>st</sup>, 18% of the blocks for Sectors 13-64 had been produced and 20 sectors total had been shipped to BNL. This was a marked increase since December. The rejection rate for blocks produced during that time was ~ 2%. In addition, 66% of the fiber assemblies for Sectors 13-64 have now been filled.

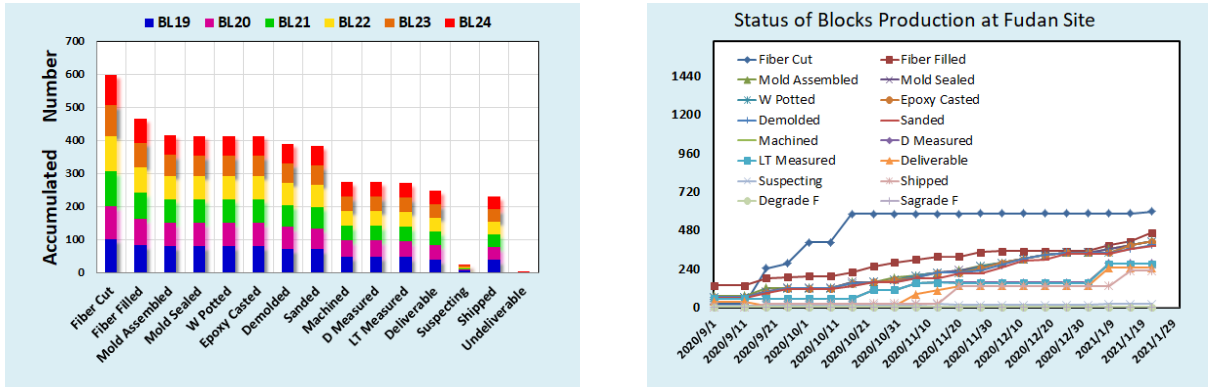


**Figure 2:** Progress on block production for Sectors 13-64 at UIUC as of January 21<sup>st</sup>.



**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 picked up after the first of the year and then had a small slowdown during the MLK holiday, but the four-week average will tend to increase this. However, the rate has not yet reached its previous high level that was achieved back in October 2020, and now needs to reach a rate of 65 blocks per week in order to be able to deliver all of the Sector 13-64 blocks on schedule by the end of 2021. This is mainly due to a need for an additional machinist in the EMCAL block factory to machine the blocks. UIUC is looking into ways to hire someone to fill this job as soon as possible.



**Figure 4.** Block production at Fudan (status as of Jan 21<sup>st</sup>). 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. Figure 4 shows the status of various stages of block production and shipment as of January 21<sup>st</sup>. The rate of block production at Fudan is reaching 20 blocks per week, and a total of 227 blocks have been shipped to BNL. All of the blocks received (with the exception of 2 that were damaged in shipment) have passed all of our standard QA tests.

Work on module production and sector assembly continued at BNL. The addition of two more techs has greatly helped increase productivity. Figure 5 shows the status of the various stages of module production as of Jan 29<sup>th</sup>. All of the modules for Sectors 1-13 have been completed and work is continuing on the modules for Sectors 13-18. The delivery problem we were having with the light guides has now been resolved and we are now receiving them on a regular basis that will allow us to keep on our schedule.

Figure 6 shows the status of sector assembly. Ten sectors have been completed and tested. Assembly is proceeding on Sector 11 and the blocks have been glued into Sectors 12 and 13 which will then proceed onto assembly. We have received enough cooling loops and strongbacks to complete up to Sector 20, but there is currently a delivery problem with the preamp boards which we expect will soon limit our ability to complete and test full sectors. However, the burn-in sector testing area is being set up and commissioned and should be operational soon.

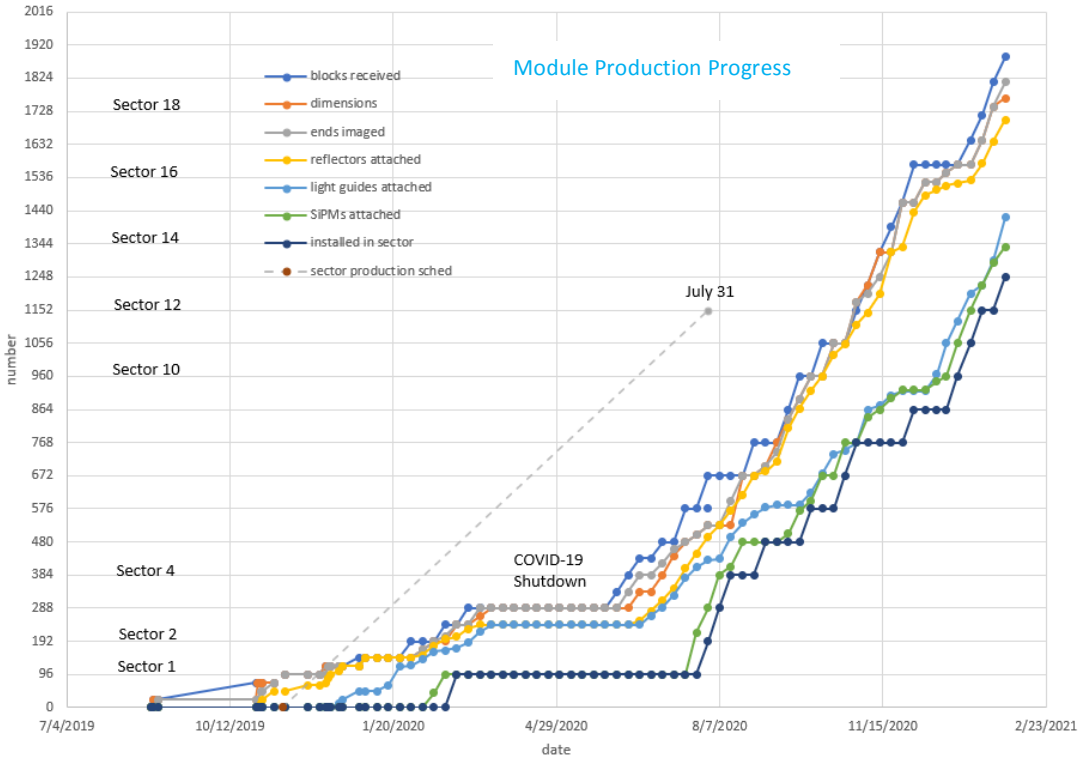
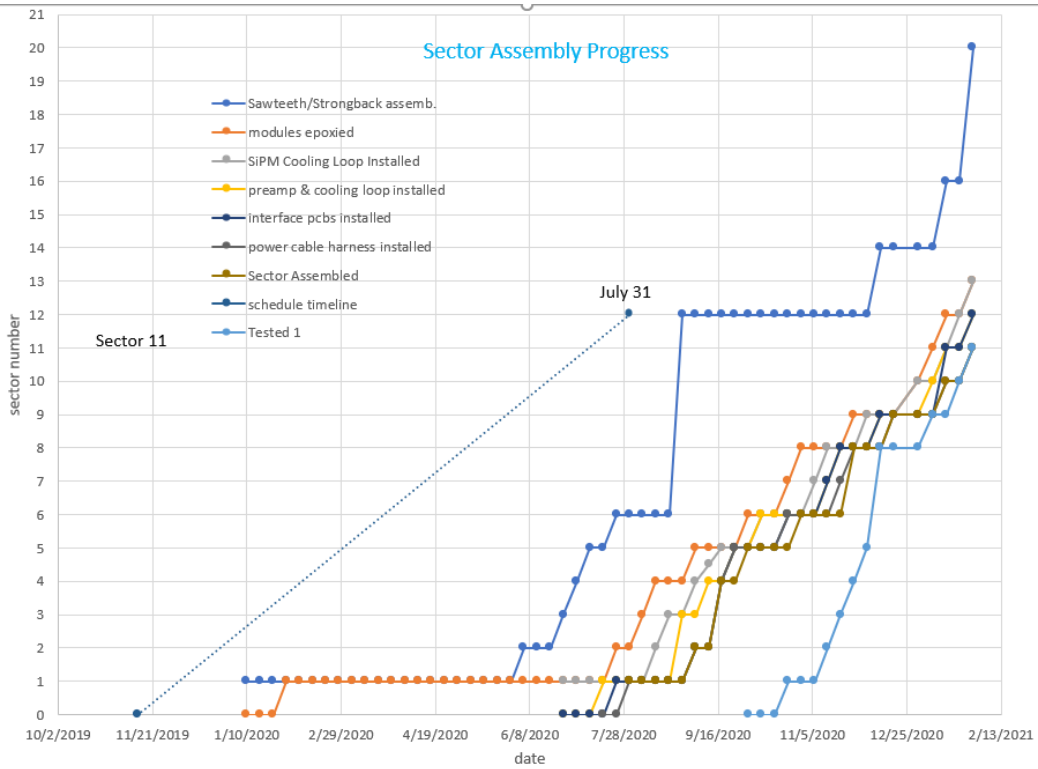


Figure 5: Status of module production at BNL as of Jan. 29th.





**Figure 6:** Status of sector assembly at BNL as of Jan 29<sup>th</sup>.

**Work For the Next 2-3 Months:**

Production of blocks for Sectors 13-64 will continue at UIUC. The rate of block production increased after the Christmas holiday but is currently limited from reaching its full capacity due to the lack of manpower for machining the blocks. Production of the high rapidity blocks for Sectors 13-64 will also continue at Fudan. They are currently producing blocks at a rate of ~ 20 blocks per week. However, it is expected that block production will be slow in China in February due to the Chinese New Year.

Module production and sector assembly will continue at BNL. There are sufficient parts to complete up to Sector 15 but after that we will not have enough preamps to continue with completing and testing full sectors. It is expected that additional preamps will not be available until some time in April. Until then, we will have to assemble sectors up to the point of installing the preamps and then set them aside until additional preamps arrive. This will require reorganizing our production procedures in order to continue with module production and while only completing partial sector assembly, and then go back and complete the partially assembled sectors after the preamps become available.

**Issues:**

The addition of two more mechanical techs to the module production and sector assembly factories in January has greatly helped to increase our productivity at BNL. Both factories are now running smoothly and we are trying to make up for the loss in schedule that occurred during the second half of last year due to lack of personnel. However, the block production factory at UIUC is still short of the personnel needed to keep up with machining of the blocks. This is reducing their efficiency and limiting them in their ability to reach their production goal of 65 blocks per week. UIUC is actively addressing this problem.

Our other major concern is the delay in the delivery of the preamps. We expect to run out of preamps by early March, after which we will not be able to complete sectors and test them. The incomplete sectors will need to be set aside and completed when the preamps start arriving again, which will be some time in April. This will not only disrupt our now smoothly running production lines, but could cause a further delay in our schedule.

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

**WBS 1.4.1 Inner Hadronic Calorimeter**

**Current Status:**

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 a vendor to provide the iHCAL mechanical sectors. Raw material has been ordered and a delivery schedule has been provided by the vendor and is being integrated into P6. 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. First article inspection is expected by 5/21/2021 with delivery of the first eight sectors shortly thereafter.

The iHCAL end ring material has been received by the vendor and material certifications approved by the BNL engineers.

**Work for the Next 2-3 Months:**

ISU and Rutgers will continue to coordinate with IHCAL frame vendor to ensure good communication and adherence to the production schedule.

**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:**

Factory operations at BNL are continuing with technician labor and collaborator support from collaborating institutions (Baruch, UC Boulder, Rutgers, Lehigh, Ohio, and ISU). The first six pre-production sectors have been fully assembled and tested, along with twelve production sectors, and all eighteen have been tested and moved to storage. Ten production sectors have been moved into the assembly area for tile and electronics and cabling installation and are in various stages of assembly. The remaining four sectors will have the high tensile-strength endplates installed prior to moving into the factor for assembly. The availability of signal and thermistor cables has been keeping up with the assembly for the past few weeks. Preparations are being made to burn-in the sectors in storage, starting in March when a burn-in test rack should be available.

A partial shipment consisting of the high-strength endplates, two of the splice plates, and a sample of the pucks and pins have been delivered to BNL. Delivery of the remainder of the order has been delayed to the end of February 2021. The vendor has indicated a lack of labor due to COVID-19 has slowed the overall production schedule. The partial delivery is currently undergoing inspection and dimensional verification by BNL technicians, but this process is also delayed for COVID-related reasons.

**Work for the Next 2-3 Months:**

Over the next several months work on the outer HCAL will center on completing production 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:** UC Boulder graduate student replaces a preamplifier on an outer HCal sector in the 912 factory.

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

#### **Current Status:**

Testing of the EMCal SiPM daughter boards continues with a failure rate of less than 1%. Testing of HCal preamps continues with the assistance of Lehigh University and Iowa State University with a yield greater than 95%. Parts for an additional three EMCal sectors worth of preamps were received by the assembly house with a projected delivery date of early February 2021. The delivery of the balance of the preamp boards is still scheduled to start in April 2021 due to long lead times on components. Weekly conversations with the assembly house are ongoing to monitor the supply chain for another partial early delivery if parts become available. BNL technicians continue to provide the interior signal cable assemblies for the OHCAL and the vendor providing the EMCal interior signal cables has continued to deliver cable assemblies on schedule.

The vendor for the bias supplies informed us of a partial delivery of the bias power modules in February 2021, with the full delivery expected to be delivered by mid-March 2021. The vendor for the LV bulk supplies has informed us that they expect to start shipping in April 2021, and a detailed delivery schedule will be provided in March of 2021. The first EMCal power rack was delivered to the EMCal group and will be used for burn-in testing

of the EMCal sectors. Design of the OHCal power rack has started and assembly will begin in February 2021. The PRR for the external EMCal and HCal signal and power cables was completed, and work has started on finalizing the procurement documentation.

The parts orders for full digitizer system are being submitted to the Columbia University purchasing department and should be placed by the end of February 2021. The Colorado group has completed the assembly of a test stand at Colorado University, and is preparing to receive the assembled boards for the 7-crate production for installation of front panels and final testing. Design of the digitizer racks is completed and final drawings are being made for the assembly of the first production digitizer rack.

**Work for the next 2-3 months:**

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

1. Continue assembly of cable assemblies for the remaining 10 HCal modules
2. Testing of EMCal SiPM boards and HCal Preamps.
3. Design and build the HCal power rack
4. Build the first Digitizer rack with a full crate operational.
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.
- Long lead time items for the EMCal preamps have delayed final delivery of boards

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

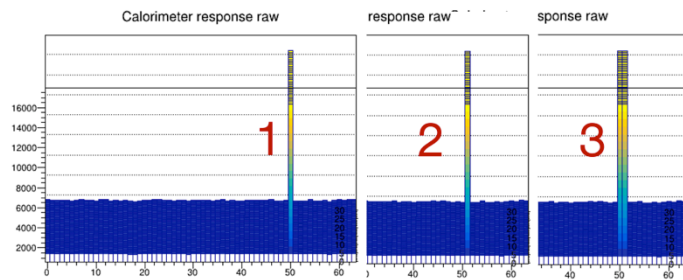
**Current Status:**

The setup of the previously procured data acquisition PCs and the Buffer Box (shown in figure 8), one of 6 total, has been completed and more systematic performance tests have been done.



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

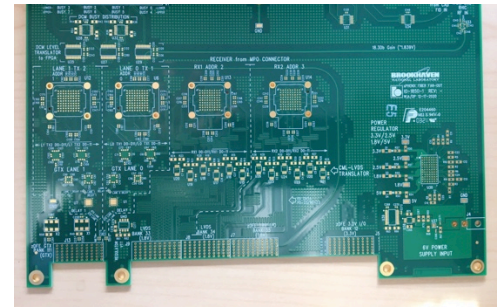
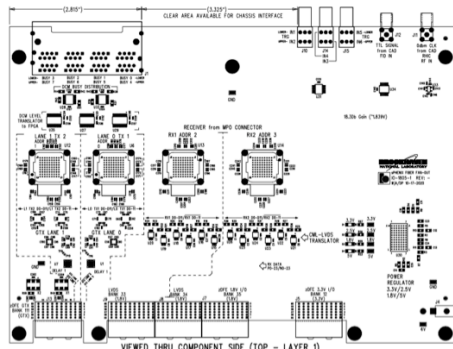
In a further, more realistic test of the future production setup, 15 individual instances of readout processes were started and controlled on 15 of the PCs, all sending their data to the buffer box. This exercises the data transfer, as well as the configuration and control of those instances, commonly referred to as “Run Control”. The previously reported test yielded 25Gbit/s using the buffer box as a NFS server, which is standard operation mode but not the most efficient. We have meanwhile implemented a dedicated data transfer protocol, called the “Super-Fast Server” (sfs), which has fewer features and performs fewer checks than the generic NFS server. It can achieve higher network throughput because it is designed specifically for our data transfer characteristics. Using this server, we were able to more than double the data transfer from 25Gbit/s to 55Gbit/s.



**Figure 9:** “Imprinting” the event number of calorimeter data

Further progress has been made in the setup for reading out multiple systems at the same time that have been described in the previous report. An important milestone is demonstrating that the different systems actually read out the same event. While we started out with “imprinting” the event number as seen by the detector-specific Granule Timing Modules (GTM), we wanted to replace this with the unique beam crossing counter. In order to accomplish that, some changes to the GTM firmware had still to be implemented. This has been completed, and this work will continue after higher-priority items are finished.

For the GL1 and Timing System, the design of an add-on board has been completed, the PCB board has been received and sent out for assembly. The board is shown in figure 10.



**Figure 10:** The layout of the GL1/GTM add-on board, on the left, and the received board on the right. The board has been sent out for assembly.

Once the add-on board is assembled and available, 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.

### **Work for the next 2-3 months :**

We will work on the further implementation of our run control software. 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:**

After looking through the multi-board test data more carefully, we found just one anomaly in the testing. When taking timing calibration test pulse through the 1.6 ns cable delay circuit, we see timing resolutions that are in the

60-70 ps range, and there is a systematic timing difference causing it. It is 30-40 ps in every other test we have done. This cable delay circuit is activated through a switch, allowing the test pulse to go through no delay, or the short cable delay. It's there to allow us to check the absolute timing calibration, and is not necessary. Also, even with the lower resolution, it still would pass the required KPP. Thus, we decided to go ahead and schedule the final design review for February 8.

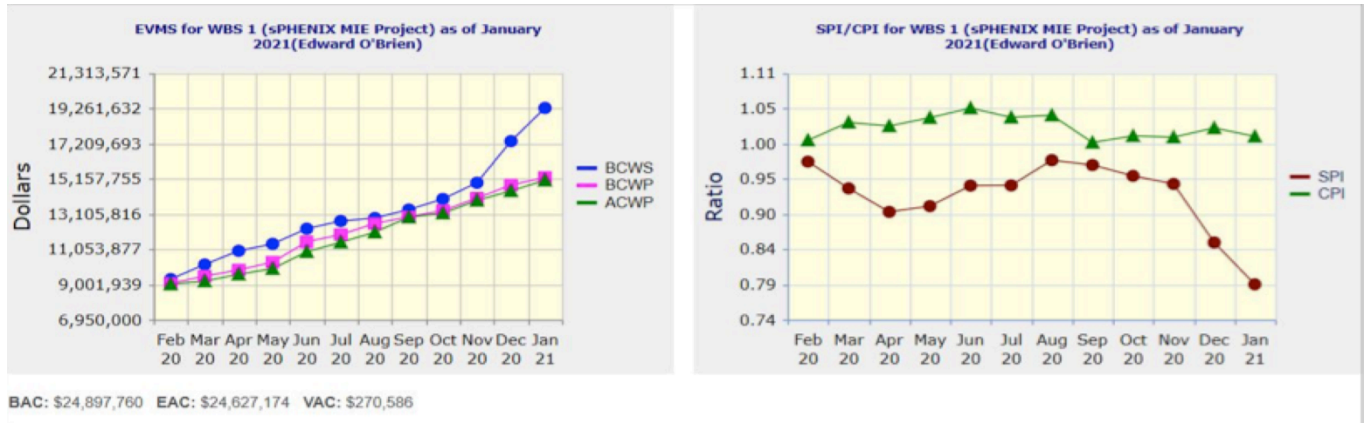
**Work for Next 2-3 Months:**

We are preparing for the Final Design Review, and following that to prepare the procurement and production testing plan. A BNL scientist continues 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 them to come to BNL in the summer and test the production electronics.

**Issues:**

None.

**SPI and CPI Trends**



Cumulative SPI	Cumulative CPI
0.79 <span style="color:red">●</span>	1.01 <span style="color:green">●</span>

Cumulative BCWS (Scheduled)	\$19,269,073
Cumulative BCWP (Performed)	\$15,220,528
Cumulative ACWP (Actual)	\$15,057,075

- 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

**January 2021 Cost Performance Report**

B. PERFORMANCE DATA												
CA (3)	CUMULATIVE TO DATE						AT COMPLETION			SPI	CPI	
	BUDGETED COST		ACTUAL COST WORK PERFORMED (9)	VARIANCE		BUDGETED (14)	ESTIMATED (15)	VARIANCE (16)				
	WORK SCHEDULED (7)	WORK PERFORMED (8)		SCHEDULE (10)	COST (11)							
ITEM (1)	(7)	(8)	(9)	(10)	(11)	(14)	(15)	(16)				
1.01A Project Management	1,819,855	1,819,855	1,682,267	0	137,587	1,951,679	1,814,091	137,587	1.00	1.08		
1.02A TPC	4,092,286	2,707,382	2,495,255	-1,384,904	212,127	5,026,775	4,667,068	359,708	0.66	1.09		
1.03A EMCal	4,963,737	4,497,278	4,776,234	-466,459	-278,956	6,070,008	6,376,233	-306,225	0.91	0.94		
1.04A HCal	2,813,551	2,537,257	2,586,996	-276,294	-49,739	4,143,416	4,199,222	-55,806	0.90	0.98		
1.05A Calorimeter Electronics	4,987,889	3,033,830	2,860,414	-1,954,059	173,416	6,290,621	6,118,312	172,309	0.61	1.06		
1.06A DAQ & Trigger	492,607	525,778	576,818	33,171	-51,040	1,245,090	1,300,716	-55,625	1.07	0.91		
1.07A MinBias Trigger Detector	99,148	99,148	79,090	0	20,058	170,170	151,533	18,637	1.00	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												
e. SUBTOTAL	19,269,073	15,220,528	15,057,075	-4,048,545	163,453	24,897,760	24,627,174	270,586	0.79	1.01		
f. Contingency						2,102,240						
g. TOTAL	19,269,073	15,220,528	15,057,075	-4,048,545	163,453	27,000,000						
9. RECONCILIATION TO CONTRACT BUDGET BASELINE												
a. VARIANCE ADJUSTMENT				0	0							
b. TOTAL CONTRACT VARIANCE				-4,048,545	163,453	0	0	0				
CLASSIFICATION (When Filled In)												
						\$9,570,099	ETC					
						\$9,677,232	BCWR					
						21.97%	% Contingency on ETC					
						21.72%	% Contingency on Remaining Work					
						77.39%	% Planned					
						61.13%	% Complete					
						60.48%	% 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



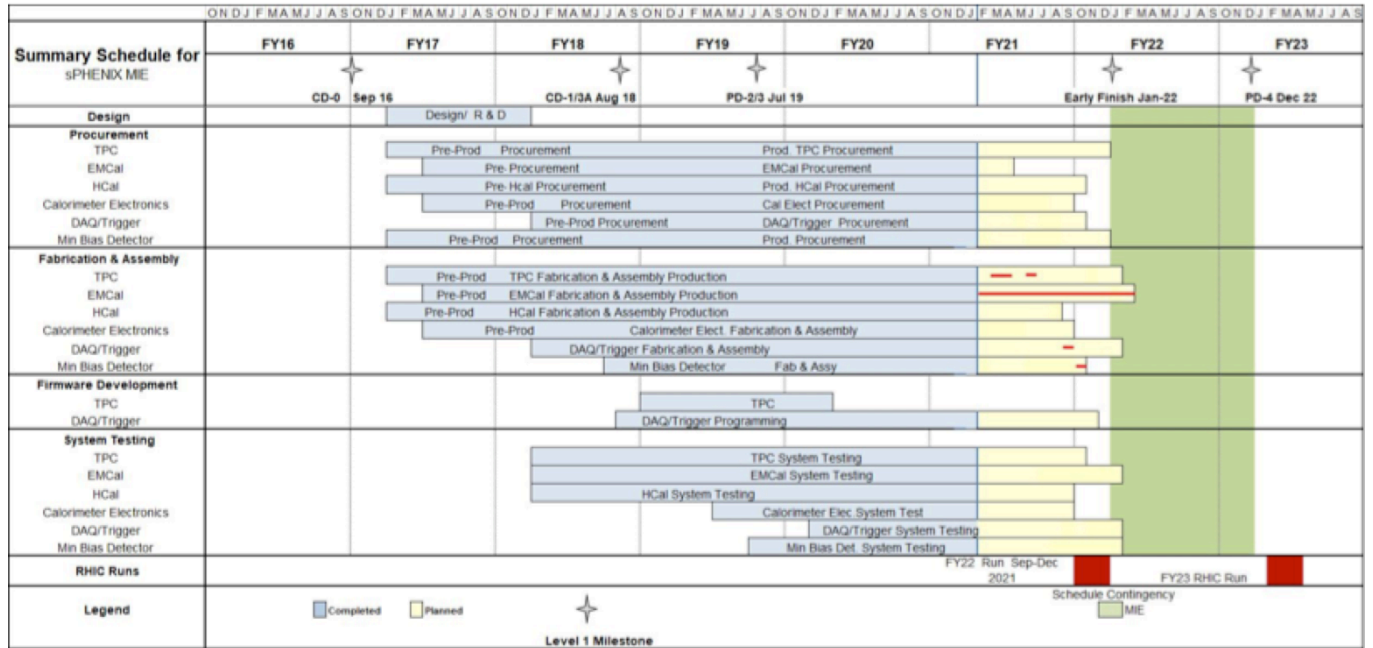
## L1 & L2 Milestones

#	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 O 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	01.06.02.03	Trigger LL1 Preproduction complete	26-Feb-21	23-Jun-21		-83
13	01.05.02.02	EMCal SiPM Boards Production Complete	31-Mar-21	30-Apr-21		-23
14	01.04.04.02	First Outer HCal Sector and Splice Plates Ready to Install	30-Apr-21	5-Mar-21		39
15	01.04.2001	Inner HCal Support Structure Ready for Installation	30-Apr-21	9-Aug-21		-69
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	18-Oct-21		-78
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	7-Oct-21		-38
21	01.05.02.02	EMCal Electronics Complete	16-Aug-21	30-Sep-21		-33
22	01.05.03.02	Calorimeter Electronics Complete	20-Sep-21	30-Sep-21		-9
23	1.07	MinBias Detector Ready to Install	30-Sep-21	26-Jan-22		-78
24	01.06.03.03	GL1 Ready to Operate	30-Sep-21	25-Jan-22		-77
25	01.01.2001	Early Project Completion	29-Oct-21	27-Jan-22		-58
26	01.02.01.08	TPC Ready to Install (Assembly Complete)	29-Oct-21	26-Jan-22		-58
27	01.02.06.03	TPC DAM Production Complete	29-Oct-21	3-Jan-22		-42
28	01.04.04.02	Last Outer HCal Sector Ready to Install	29-Oct-21	31-Aug-21		40
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	20-Jan-22		-54
31	01.06.02.04	LL1 Ready to Operate	29-Oct-21	20-Jan-22		-54
32	01.03.02.03.03	EMCal Ready to Install	29-Nov-21	26-Jan-22		-40
33	01.01.2001	Approve Project Closeout PD-4	30-Dec-22	29-Dec-22*		0

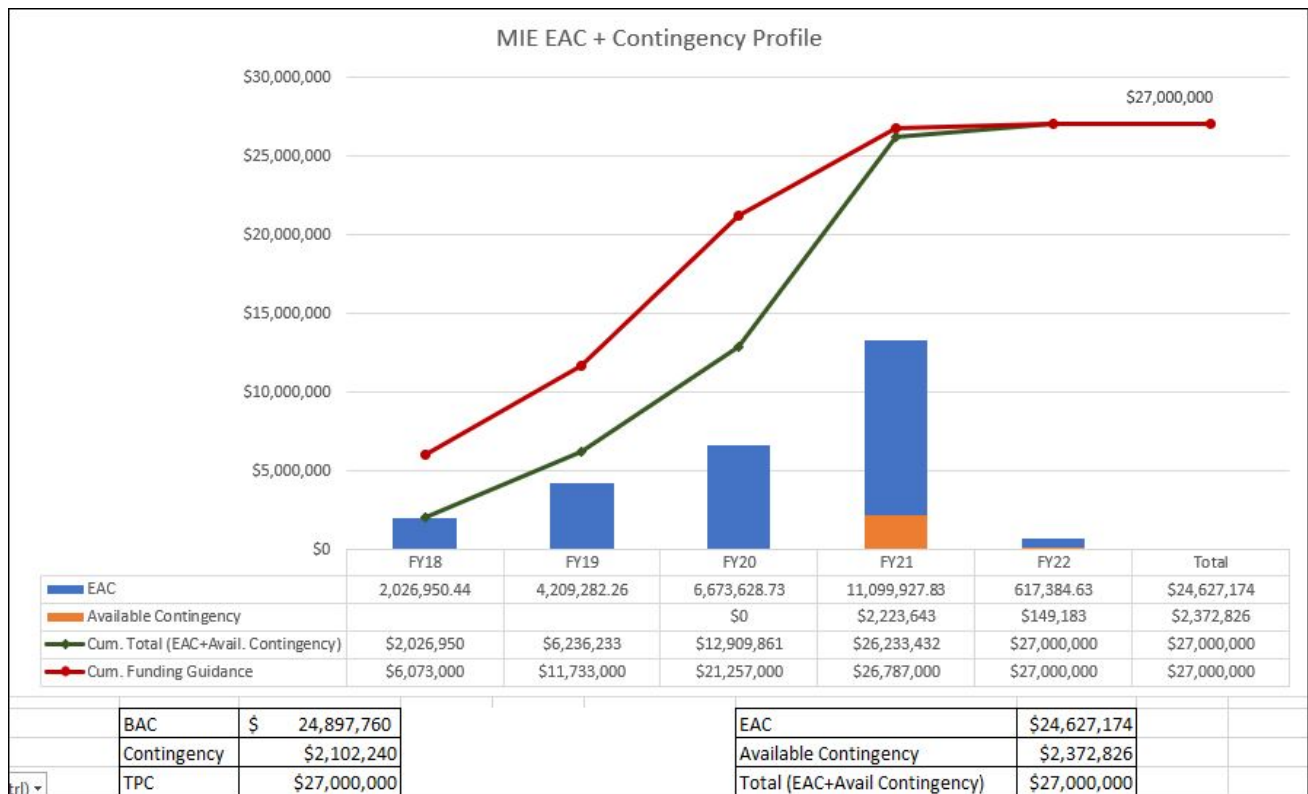
## SPHENIX Budget Profile:

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								
<b>OPC (R&amp;D+CDR)</b>		<b>1,613</b>	<b>4,460</b>	<b>350</b>				<b>6,423</b>
<b>TEC</b>				<b>5,310</b>	<b>9,524</b>	<b>5,530</b>	<b>213</b>	<b>20,577</b>
<b>Total Project Cost</b>		<b>1,613</b>	<b>4,460</b>	<b>5,660</b>	<b>9,524</b>	<b>5,530</b>	<b>213</b>	<b>27,000</b>

## Summary Schedule with critical path



## Estimate at Completion Profile





## **Variance Analysis**

January 2021

Cumulative BCWS \$19,269,073

Cumulative BCWP \$15,220,528

Cumulative ACWP \$15,057,075

SV = -\$4,048,545

CV = +\$163,453

SPI = 0.7899

CPI = 1.0109

The following report discusses the major sources of schedule variance, including all items comprising 1% of the total schedule variance, plus a few select other items, and discusses the impact as well as the corrective actions taken. The analysis is done at level 3 of the Work Breakdown Structure. An accompanying Excel file shows BCWS, BCWP, SV and status for the various item noted in the following text.

### **WBS 1.2.1 TPC Mechanics**

Description – One activity, S120100 Production of GEM foils, has an SV of -\$84,619, 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.

Impact – None as yet. All delivered GEM foils, some 29% to date, have been mounted on frames and prepared for assembly into readout modules for the TPC.

Corrective – 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**

Description – One activity S125100 TPC R1 padplanes is not complete, with an SV of -\$50,113. This in turn delays two successor activities, S125500 TPC R1 modules build, with SV = -\$28,980 and S125600 TPC R1 Modules test, with SV = -\$23,966. The total SV resulting is -\$103,058. 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.

Impact – 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.

Corrective – The signal trace routing issue has been resolved, the routing of the board is complete, and the contract for the manufacture of the pad-plane circuit cards has been placed with the same vendor who successfully built all the pad-plane circuit cards for R2 and R3 modules. The vendor has quoted a delivery time compatible with the schedule for R1 module assembly.

### **WBS 1.2.5 TPC Front End Electronics.**

Description – There are five activities with significant SV. They are:

activity S136500 TPC FEE Cooling System, SV = -\$69,821,

activity S141500 TPC FEE Production components (optical transceivers), SV = -\$34,429,

activity S141800 TPC FEE Production Components, SV = -\$61,910,

activity S142500 TPC FEE Low Voltage Power system, SV = -\$209,565,

and activity S143250, TPC FEE protective elements/diodes, SV = -\$67,983.  
The net SV is -\$443,708.

Impact – None as yet. The key activity is the FEE Production, which is ahead of schedule.

Corrective – All the items covered by these activities are being ordered, with one exception, the optical transceivers, which are being tested in February for operation in magnetic field. The required design and procurement reviews are complete. The cooling system requires a series of machined parts, for which the procurement 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 three months. The TPC FEE Protection elements/diodes are on order and scheduled to be delivered in February.

#### **WBS 1.2.6 TPC Data Aggregator Modules**

Description – 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 S138400 EBDC computers and peripherals, SV =-\$244,769.

All these items have delivery dates in January thus all three are new additions to the negative SV.

Impact – None

Corrective – The EBDC computer prototype passed all tests. The production order is being prepared for submission to Procurement. 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. 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). It has just been realized this topology needs an update, meaning the bill of materials for the fiber optic components must be revised. This revision will be completed in February.

#### **WBS 1.2.7 TPC Support Systems**

Description – There are three areas of effort. The TPC Lasers delivery has started but only the first article has been delivered, SV =-\$210,418. The TPC Gas System has procured and received 25% of the components but still needs to place requisitions for the balance, SV =-\$97,008. The TPC Cooling system has not procured the high value elements including the chiller, SV =-\$76,175.

The total SV for these key items is -\$383,601.

Impact – 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.

Corrective – The Preliminary Design reviews are complete and all three of these subsystems have moved to acquiring first articles. Proper operation is to be demonstrated prior to holding the Final Design reviews and the Procurement Readiness reviews, which are expected by March.

#### **WBS 1.3.1 EMCal Blocks**

Description – There are four main items causing the SV. The S171800 Epoxy is only 32% complete, SV =-\$31,987. Molds S172500 and fiber assemblies S172800 are behind schedule, SV =-\$27,995. The S174000-S175500 Blocks for Sectors 23-38 are not complete, SV =-\$82,202, nor is their shipping to BNL, SV =-\$18,694.

The total SV for these items is -\$160,878.

Impact – None

Corrective – 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 has been adjusted to reflect this.

### **WBS 1.3.2 EMCal Modules and Sectors**

Description – The S187400 Production Light Guide contract is not complete, SV = -\$204,110. The S195400 Mechanical parts for Final Sectors are not yet all received, SV = \$102,111. The total of these SVs is -\$306,221.

Impact – None

Corrective – 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/strongback in fact being complete; the sawteeth delivery schedule is about a month ahead of need-by date.

### **WBS 1.4.2 Outer HCal Mechanics**

Description – The S205100 Splice Plates are not yet delivered, SV = -\$303,325.

Impact – None, the current delivery schedule is still 3 months ahead of need.

Corrective – Continued contact with the vendor. The vendor had to reject some of the initial parts due to an issue of cracks developing in the steel after heat treating and subsequent machining. The technique for heat treating was changed, a different method of machining the precision holes was selected and employed, and the problem has not recurred. Delivery of first parts is planned for February and delivery of the balance of the contract is planned for March.

### **WBS 1.5.2 Calorimeter Front End Electronics**

Description – Eight separate activities contribute substantially to this SV. They are:  
activity S226400 EMCal external bias power system for sectors 1-12, SV = -\$29,456,  
activity S227605 EMCal SiPM daughter boards part 2, SV = -\$18,565,  
activity S229300 EMCal preamplifiers not delivered, SV = -\$549,642,  
activity S231800 EMCal internal cables are only 45% complete, SV = -\$158,506,  
activity S233250 EMCal trunk signal cables are not complete, SV = -\$189,831,  
activity S234100 EMCal LV power system sectors 13-64 only 20% complete, SV = -\$31,416,  
activity S244400 HCal External cables are only 20% complete, SV = -\$81,552, and  
activity S244450 HCal trunk signal cables not complete, SV = -\$36,439.

The total SV for these activities is -\$1,095,407.

Impact – none except for the EMCal preamps, which will be needed by the EMCal sector production line starting in early March.

Correctives – The contract is placed for the EMCal preamplifiers. We have negotiated with the vendor to deliver a first batch, adequate to instrument more than 3 sectors, as soon as possible to help with completion of EMCal sectors. The vendor anticipates being able to meet the March schedule for these first preamplifier units using parts in hand. The vendor is also currently obtaining all the long-lead-time parts for the main EMCal preamplifier production.

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 are being prepared. Potential vendors indicate they can meet the requested delivery schedule for these cables.

### **WBS 1.5.3 Calorimeter Digitizers**

Description – There are two activities contributing to this SV. One is S252700 Digitizer Parts, SV = -\$678,538 and the other is S252800 Digitizer Boards, SV = - \$149,785.

Impact – None presently. The EMCal and OHCal sector production lines have an adequate number of digitizers to perform all needed QA during remaining detector construction. Thus the remaining digitizers are only needed by the completion of the MIE project.

Corrective – 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**

Description – Three activities have been completed ahead of schedule, resulting in a positive SV = \$203,950.

These activities are S257600 Sub-Event-Buffer board production, SV = \$47,634, S258400 Assembly and Trigger Processor board production, SV = \$113,823, and finally S259500 Buffer Box procurement, SV = \$41,513.

Impact – None

Corrective – None, activities were completed early.

### **WBS 1.6.2 Local Level-1 Trigger**

Description – Activity, S263600 Preproduction Local Level-1 trigger, is not complete, resulting in SV = -\$69,641.

Impact – None

Corrective – 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. It is anticipated the tests will continue until late February, at which point a review will be conducted. It is expected based on results to date that this review will determine that the production Local Level-1 trigger boards can be manufactured during 2021 based on the present design using 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**

Description – Activity S267600 Production of final GL1 is not complete, SV =-\$32,673.

Impact – None

Corrective – 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 planned to last until early March. Assuming a positive outcome, the production Global Level-1 Trigger will be assembled using the existing blueprints.

### **WBS 1.6.4 Timing System**

Description – Activity S270300 Production of Timing System is not complete, SV =-\$48,284.

Impact – None

Corrective – 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 planned to last until early March. Assuming a positive outcome, the production Timing System will be assembled using the existing blueprints.