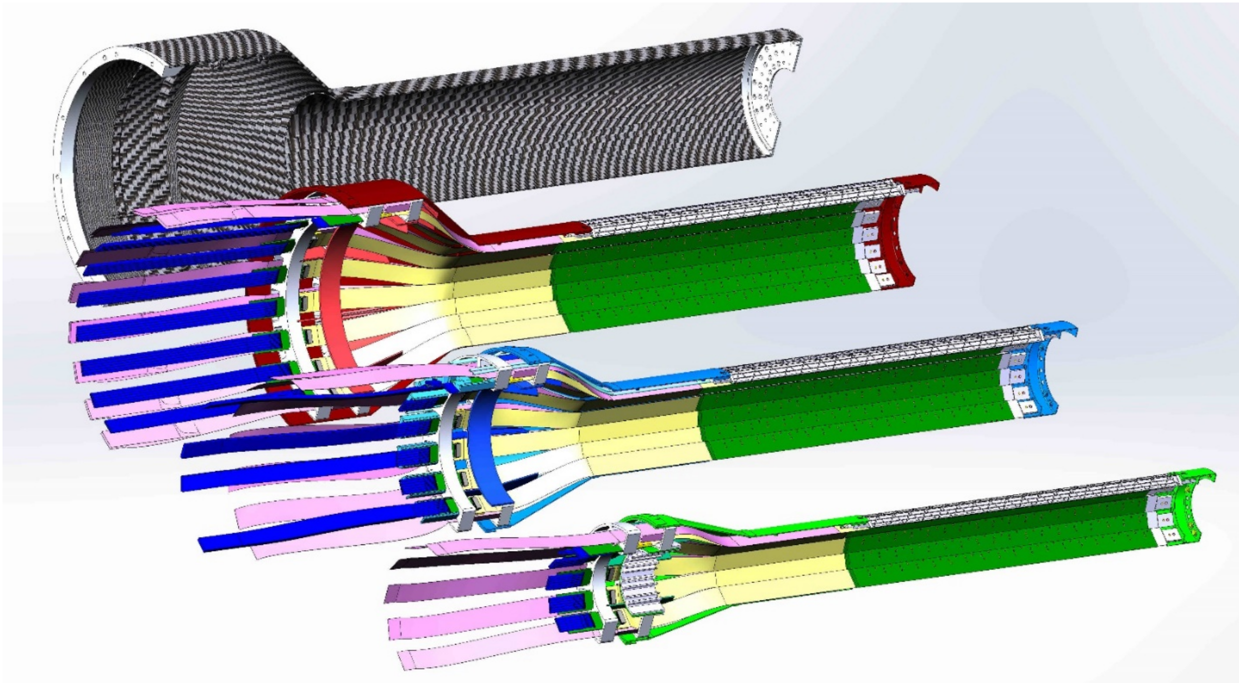


Management Plan

for

A Monolithic-Active-Pixel-Sensor-based Vertex Detector (MVTX) Upgrade for the sPHENIX Experiment

at the

Brookhaven National Laboratory

July 25, 2019 (V6)

1 INTRODUCTION

sPHENIX is a next-generation nuclear physics experiment providing world-class capabilities for multi-scale studies of the strongly coupled quark gluon plasma (QGP), planned for the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory in 2022 and beyond. The need for these capabilities to advance our understanding of the origins of novel QGP properties is detailed in the 2015 NSAC Long Range Plan.

Precise measurements of heavy flavor-tagged jets and B-hadron nuclear modification and flow in heavy ion collisions are key scale-dependent observables. Measuring these rare observables demands high precision tracking with excellent displaced secondary vertex capabilities. While the baseline sPHENIX detector anticipates a small aperture detector for secondary vertexing, exploiting the full potential of heavy flavor QGP signatures, and optimizing the use of RHIC luminosity and available running time, is only possible with a large acceptance precision vertex detector. We propose to build a thin, extremely precise silicon pixel vertex detector for the sPHENIX experiment to enable these key measurements. The detector will be based closely on the latest generation of Monolithic-Active-Pixel-Sensor (MAPS) technology, developed for the ALICE collaboration at CERN, and leveraging the extensive R&D investments made in this technology over a period of several years. Last summer, the Los Alamos National Laboratory High-Energy Nuclear Physics Group was awarded an internal LDRD grant ($5M over 3 years, FY17-19) to develop a state-of-the-art MAPS-based telescope to demonstrate the tracking capability of such a device for the sPHENIX experiment. The LANL LDRD will allow us to carry out the much needed early R&D for the MAPS readout electronics and produce the initial conceptual design of mechanical system integration into the sPHENIX detectors, and also develop a state of the art theoretical calculation, modeling and full physics simulations and analyses with a realistic detector configuration.

2 Project Baseline

2.1 Physics

The MAPS-based Vertex Detector (MVTX) is proposed to be ready for Day-1 sPHENIX data taking. To meet this challenge, we propose to use the same ALICE ITS upgrade facilities at CERN to continue producing MAPS staves for the sPHENIX MVTX project, starting from mid 2018 following the completion of ALICE production. This detector will provide world-class scientific results in key areas encompassed by the DOE Nuclear Physics mission. It will allow U.S. scientists to make fundamental inquiries into the nature of the QGP that cannot be probed with other existing facilities worldwide. In particular, the sPHENIX experiment, which was granted with DOE CD-0 in September 2016, will complement and extend the ongoing and future QGP studies at RHIC and LHC, and will become the next generation U.S. flagship high energy nuclear physics program at the DOE’s key facility in this field.

The physics goals of the proposed vertex detector project are aligned with the key challenges and physics opportunities outlined in the 2015 NSAC Long-Range Plan: “There are two central goals of measurements planned at RHIC, as it completes its scientific mission, and at the LHC: (1) Probe the inner workings of QGP by resolving its properties at shorter and shorter length scales. The complementarity of the two facilities is essential to this goal, as is a state-of-the-art jet detector at RHIC, called sPHENIX. (2) Map the phase diagram of QCD with experiments planned at RHIC.”

The key approach for goal (1) is microscopy of the QGP through probes that are sensitive to characteristic scales in the plasma. The baseline sPHENIX design is optimized to employ light quark and gluon jets over a wide kinematic range and Upsilons as such scale-sensitive probes. The vertex detector described in this proposal will greatly expand the sPHENIX capabilities in an additional dimension related to scales in the QGP, by allowing a range of precision studies as a function of parton mass. Studies of heavy-flavor hadrons have been a focus of recent upgrades in sPHENIX and STAR at RHIC. These studies, as well as new measurements by the current LHC experiments form the key motivation for the ALICE Phase-I upgrades for the early 2020’s. In combination with the large acceptance and high rate capability of sPHENIX, the vertex detector upgrade provides access to observables that are not accessible with the present RHIC detectors and are complementary to those at LHC.

Heavy flavor quarks (c, b) play a unique role for studying the QCD in vacuum as well as at finite temperature or density. Their masses are much larger than the QCD scale (L_{QCD}), the additional QCD masses due to chiral symmetry breaking, as well as the typical medium temperature created at RHIC and LHC. Therefore, they are created predominantly from initial hard scatterings and their production rates are calculable in perturbative QCD. They are thus calibrated probes that can be used to study the QGP in a controlled manner.

The vertex detector will enable a wide range of heavy-flavor studies, extending present RHIC measurements to significantly larger transverse momenta, and provide access to qualitatively new QGP signatures. A new capability, in combination with the sPHENIX calorimetric jet reconstruction, is the identification of jets originating from heavy quarks. In this proposal, we will use the measurements of b-tagged jets as a case study to illustrate the new capabilities the upgrade brings to RHIC and the overall field. This measurement represents both a new opportunity at RHIC and an example of complementarity to the LHC: the projected sPHENIX measurement both extends the LHC measurement to lower transverse momenta and provides a kinematic overlap, where the same jets can be studied in the different QGP conditions at RHIC and LHC.

2.2 KEY FUNCTIONAL REQUIREMENTS

The principal functional requirement of the MVTX is to provide precise measurements of tracks back to the collision vertex with a transverse distance of closest approach (DCA) resolution on the order of 25 μm or better. The MVTX project will be complete when the parameters (KPPs) in Table 2 have been demonstrated through bench tests and the deliverables in Table 1 are satisfied. Installation and integration of these delivered components and parallel activities associated with sPHENIX MIE are not part of this project's scope.

General requirements:

- The system must fit into the integration envelope agreed to within sPHENIX
- The system must be able to operate inside the sPHENIX magnet.
- The system must be safe. The system must meet BNL Collider-Accelerator Department (C-AD) safety requirements.
- The system must not interfere with the VT other detector subsystems.
- Each stave must have a radiation length of less than 0.5 %.
- The system must operate in a temperature range of 0º C to 30º C.
- The noise hit rate for each MVTX shall be less than 0.01% for a threshold of ~2000 electrons.
- Survive 200 krad integrated radiation dose over 10 years.
- The MVTX will function properly under all beam species.
- The MVTX system must work within the existing sPHENIX readout scheme,
    - must store the data for the LVL1 latency (4 μs),
    - must have a 4-deep buffer of LVL1 accepted events,
    - must readout data within 100 μs to its front-end modules (FEMs) off the detector so as to not significantly reduce the maximum rate of sPHENIX Level-1 triggers which is designed to be 10 kHz.

Table 1. MVTX Deliverables

ITEM	Quantity	Spares
RU*	48	12
Felix Board	6	2
Staves*	48	36
½ Barrel Assembly	2	0
Power Supply	1	0
Service Barrel	1	0

*The RU and Staves are not part of the cost of MVTX project but are still a deliverable.

The Large number of stave spares allows the construction of a two-layer barrel detector should the three-layer detector suffer a catastrophic failure.

A subset of these requirements is summarized in Table 2 and represents the Key Performance Parameters (KPPs) that the project will be responsible for delivering at the project close-out. KPPs will be determined from testbench pulser, cosmics and calibration runs to demonstrate the MVTX detector is working at a performance level that is consistent with the design.

Table 2. sPHENIX MVTX System Key Performance Parameters (KPPs)

Pixels active	>80%
Hit efficiency	>90%
Radiation length per wedge	< .5 %
Detector hit resolution	< 25 μm
Noise hits/chip	< 0.01%
LVL1 latency	4 μs
LVL1 Multi-Event buffer depth	5 events
Read-out trigger rate	> 15 kHz

In addition to these KPPs, Ultimate Performance Parameters (UPPs) have been defined, based on the actual performances from lab bench test and also the recent STAR HFT and TPC. The UPPs are listed in Table 2 and describes the performance needed after the project completion to realize the scientific goals of the project. These parameters are outside the MVTX project's scope.

Table 3. sPHENIX MVTX System Ultimate Performance Parameters (UPPs)

DCA resolution	<50um for charged hadrons (pions) at pT = 1GeV/c
Tracking efficiency	>60% for charged hadrons (pions) at pT = 1GeV/c in the 10% most central Au+Au collisions

2.3 TECHNICAL SCOPE

The sPHENIX MVTX project is divided into three major subsystem groups: (a) ALPIDE chip, High Density Interconnect (HDI) and cooling plate, collectively termed the stave assembly, (b) DAQ electronics, and (c) mechanical and infrastructure. A summary of the design parameters of the MVTX is given in Table 2.

Table 3. Summary of main design parameters of each MVTX

	Layer 0	Layer 1	Layer 2
Radial position (min.) (mm)	24.6	32.0	39.9
Radial position (max.) (mm)	28.0	35.9	43.4
Length (sensitive area) (mm)	271	271	271
Active area (cm^2)	421	562	702
Number of pixel chips	108	144	180
Number of staves	12	16	20

2.4 Cost Breakdown

The budget summary for the MVTX project is shown in Figure 4. . The inflation adjusted costs of the MVTX project is $ 3.9 M. The breakdown for costs in FY19 dollars is shown in Table 3. The electronics costs are manly for procurements because the R&D effort was covered under a LANL LDRD. The largest cost item is WBS 3.02.3.02.03

Figure 4. Cost breakdown in FY 19 dollars. No contingency is included.

WBS	Level 2 WBS Description	Burdened AY$ labor	Burdened AY$ M&S	Burdened AY$ Total
3.02.3.02.01	MVTX Project Management	$498.8k	$46.8k	$544.6k
3.02.3.02.02	MVTX Electronics	$211.2k	$358.4	$569.6k
3.02.3.02.03	MVTX Mechanics and Detector Assembly	$1241.6k	$667.0K	$1908.6k
3.02.3.02.04	MVTX Integration and Installation	$456.8k	$416.5k	$873.3k
	Total	$2187.8k	$1500.6k	$3688.5k

2.5 Schedule

The WBS schedule was begun using MS Project and we have continued using that to get a final version. We are now at a point where the final version has been transmitted to BNL for inclusion into the overall sPHENIX P6 file. We have used the current P6 file (16-July-19) for the information in this PMP. A simplified schedule is shown in figure 1. The current WBS schedule is in Appendix 1

2.5.1 MVTX Project Schedule Baseline

The current schedule has the stave and RU production being done at CERN (started) and covered under separate funding and not part of this PMP. Some of the detector and interface design has already begun before September 2019 through conceptual design efforts performed under the LANL LDRD. With a MVTX project start date of September 2019, the MVTX is ready for commissioning at the end of August 2022. The beginning installation of the MVTX is constrained by the finish date of the sPHENIX 8/2022. The fully tested silicon half-barrels are delivered to BNL for full system tests in 1st Qtr of FY2022. The electronics arrive at BNL in summer 2020.

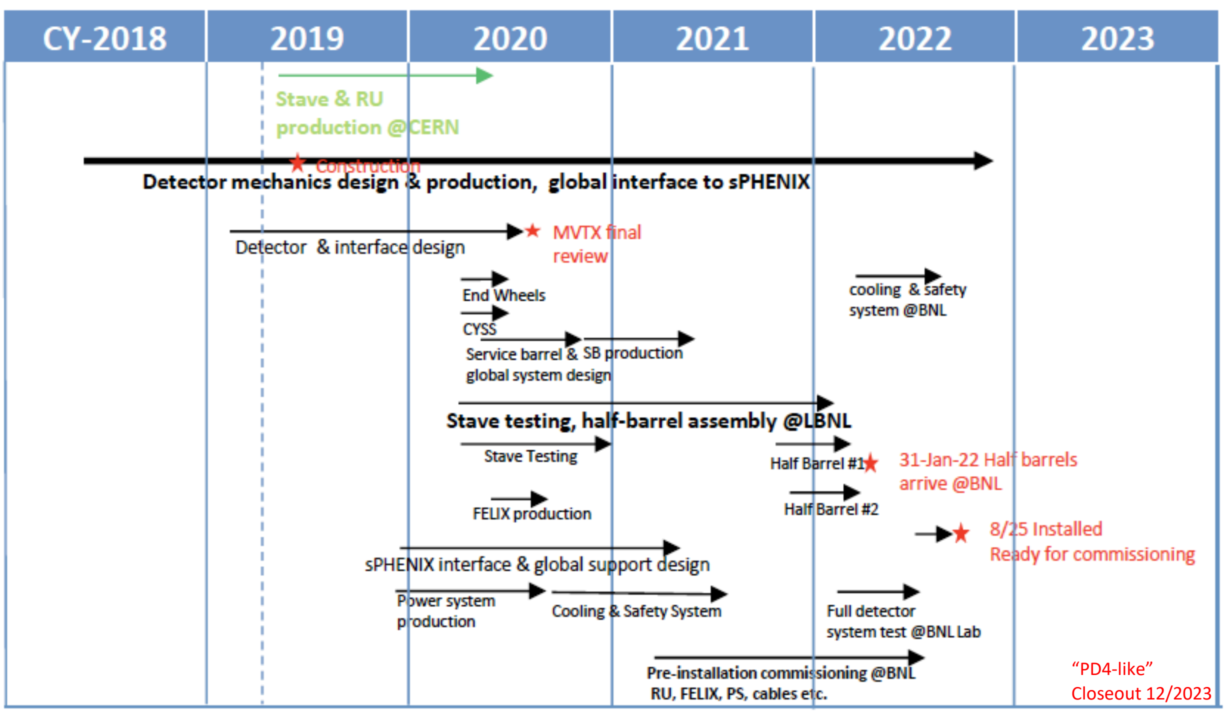


Figure 1. Simplified schedule showing the MVTX will be ready for beam at the end of FY 2022.

The fully tested half barrels arrive at BNL for testing and installation in sPHENIX at BNL in mid FY2021.

2.5.2 Milestones and Key Tasks

Milestones will be used to mark the progress of scheduled tasks. A milestone may mark the start, an interim step, or the end of one or more activities as needed to provide insight into the project's progress. The following Table 4 detail the high level milestones for the project. In addition, there are several lower level milestones in the project WBS schedule.

Table 4 Milestones and Key Tasks

Milestone	Date
Start Project	4th Qtr FY2019
SamTec Cables Prod. Contract Awards	3rdQtr FY2020
Felix v2.0 Prod. Contract Awards	2nd Qtr FY2020
All 84 Staves received	4th Qtr FY2020
End Wheel Tooling Design	2nd Qtr FY2020
CYSS Design	2ns Qtr FY2020
Service Barrel Design	3rd Qtr FY2020
MVTX Final Design Review	4th Qtr FY2020
Complete End Wheels	4th Qtr FY2020
Complete CYSS	4th Qtr FY2020

Complete SB	1st Qtr FY2021
Procure Support Structures Contract Awards	1st Qtr FY2021
Half Barrels Assembled	1st Qtr FY2022
MVTX ready for Installation in sPHENIX	2nd Qtr FY2022
Installation Finished	4th Qtr FY2022
Ready for Beam	1st Qtr FY2023
Project Closeout	1st Qtr FY2024

2.5.3 Work Breakdown Structure (WBS)

The MVTX project has been organized into a WBS for the purposes of planning, managing and reporting project activities. Work elements are defined to in Table 5

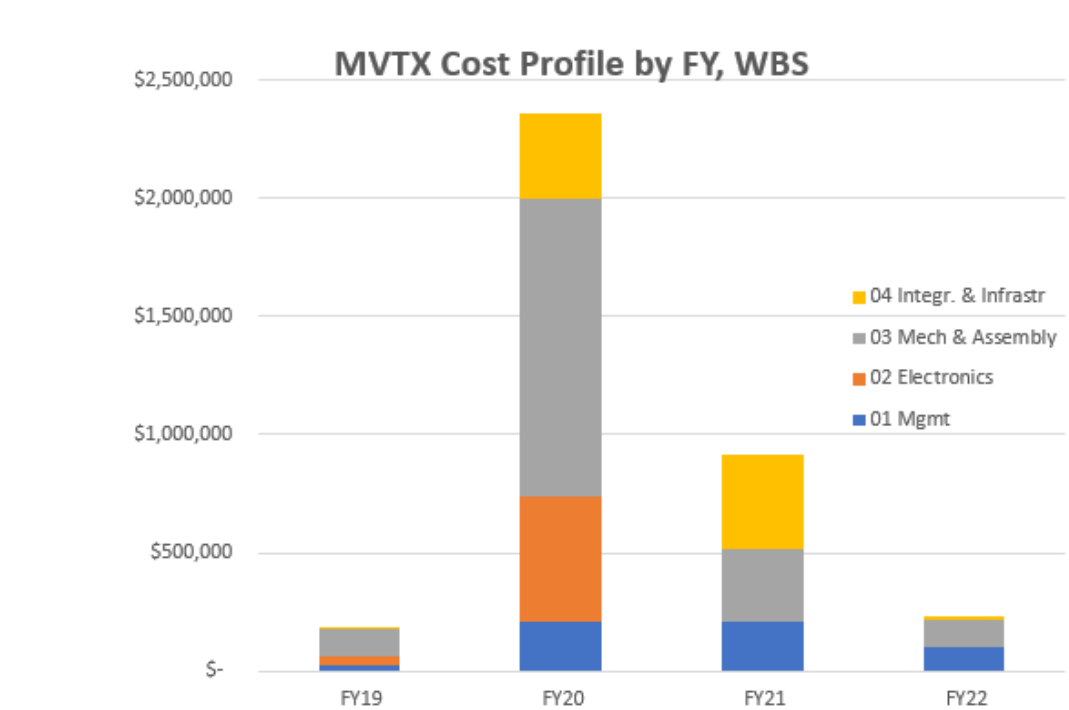
Table 5 Work Breakdown Elements

WBS	Work Elements	Effort
POM2B_3.02.3.02.01	Management	Level of effort tasks associated with the daily management, oversight, and assessment of the project. Oversight, documentation, and reporting, included.
POM2B_3.02.3.02.02	Electronics	Procurement of off project developed electronics, testing, and installation into MVTX.
POM2B_3.02.3.02.03	Mechanics and Detector Assembly	Design, production, and installation of the carbon structures to support the silicon staves, and enclosure to transport the electronics cables to the electronics racks locate outside of the sPHENIX magnet.
POM2B_3.02.3.02.04	Integration and Infrastructure	Incorporates the effort to integrate the MVTX subsystem into the rest of the sPHENIX detector. Includes the details of the designs of the support structures for the INTT and TPC. Includes the cooling designs, safety systems, infrastructure for utilites that adhers to BNL standards. Defines the Installation sequence of the MVTX into sPHENIX.

Summary of MVTX WBS

WBS Number	WBS Name
3.02	MVTX
3.02.00	External Milestones in WBS 3x from WBS 1x, 2x
3.02.01	MVTX Project Management
3.02.02	MVTX Electronics
3.02.02.01	Readout Unit (RU)
3.02.02.02	FELIX 2.0
3.02.02.03	MAPS Power System
3.02.02.03.01	Power Boards
3.02.02.03.02	Power Supplies
3.02.03	MVTX Mechanics and Detector Assembly
3.02.03.01	Staves
3.02.03.01.01	Production
3.02.03.01.02	Stave Assembly Tooling
3.02.03.01.03	Metrology
3.02.03.01.04	Shipping and Storage Containers
3.02.03.01.05	Shipping the Staves from CERN to LBNL
3.02.03.02	Carbon Structures
3.02.03.02.01	Mechanics Detector Design
3.02.03.02.02	End Wheels
3.02.03.02.03	Mechanics Fabrication
3.02.03.02.03.01	Cylindrical Support Structure (CYSS)
3.02.03.02.03.02	Service Barrel (SB)
3.02.03.02.04	MVTX Final Design Review
3.02.03.03	Barrel Assembly
3.02.03.03.01	Assembly and Testing
3.02.03.03.01.01	Layer Assembly and Test
3.02.03.03.01.02	Half Barrel #1 Assembly and Test
3.02.03.03.01.03	Half Barrel #2 Assembly and Test
3.02.04	MVTX Integration and Infrastructure
3.02.04.01	Cooling System
3.02.04.02	Safety Systems
3.02.04.03	Service Barrel Support Frame & MVTX Interface to sPHENIX
3.02.04.04	Half detector Assembly Readout and Cooling Test at BNL

2.6 Funding Profile



	FY19	FY20	FY21	FY22	Total by WBS
01 Mgmt	$ 23,540	$ 210,128	$ 209,596	$ 101,338	$ 544,602
02 Electronics	$ 41,687	$ 527,895			$ 569,582
03 Mech & Assembly	$ 112,831	$ 1,257,896	$ 307,183	$ 113,468	$ 1,791,378
04 Integr. & Infrastr	$ 3,200	$ 364,985	$ 399,262	$ 15,491	$ 782,939
Grand Total	$ 181,258	$ 2,360,904	$ 916,041	$ 230,297	**$ 3,688,501**

The funding spike in FY2020 is due to the engineering design and fabrication of the carbon structures.

2.7 Planned BNL Funding

The MVTX project is funded out of the BNL operations budget spread over 5 years.

2.8 Baseline Change Control

Changes to the approved technical, cost, and schedule baselines will be controlled using the thresholds described in Table 6-1 .

The change request will be initiated by the sub-system manager regarding a change to the cost, schedule, or technical baseline. A draft Project Change Request is generated by PM and pertinent data/documents are attached.

All Level 3 PCRs will be approved by the PM. Level 1 and 2 PCRs will be submitted by the PM to the Physics Department Associated Chair person for Nuclear Physics. All Level 2 PCRs will be reviewed and approved by the Physics Department associate Chair. For PCRs exceeding the thresholds of Level 2, they will forward them to the ALD for Nuclear and High Energy Physics with a recommendation for approval.

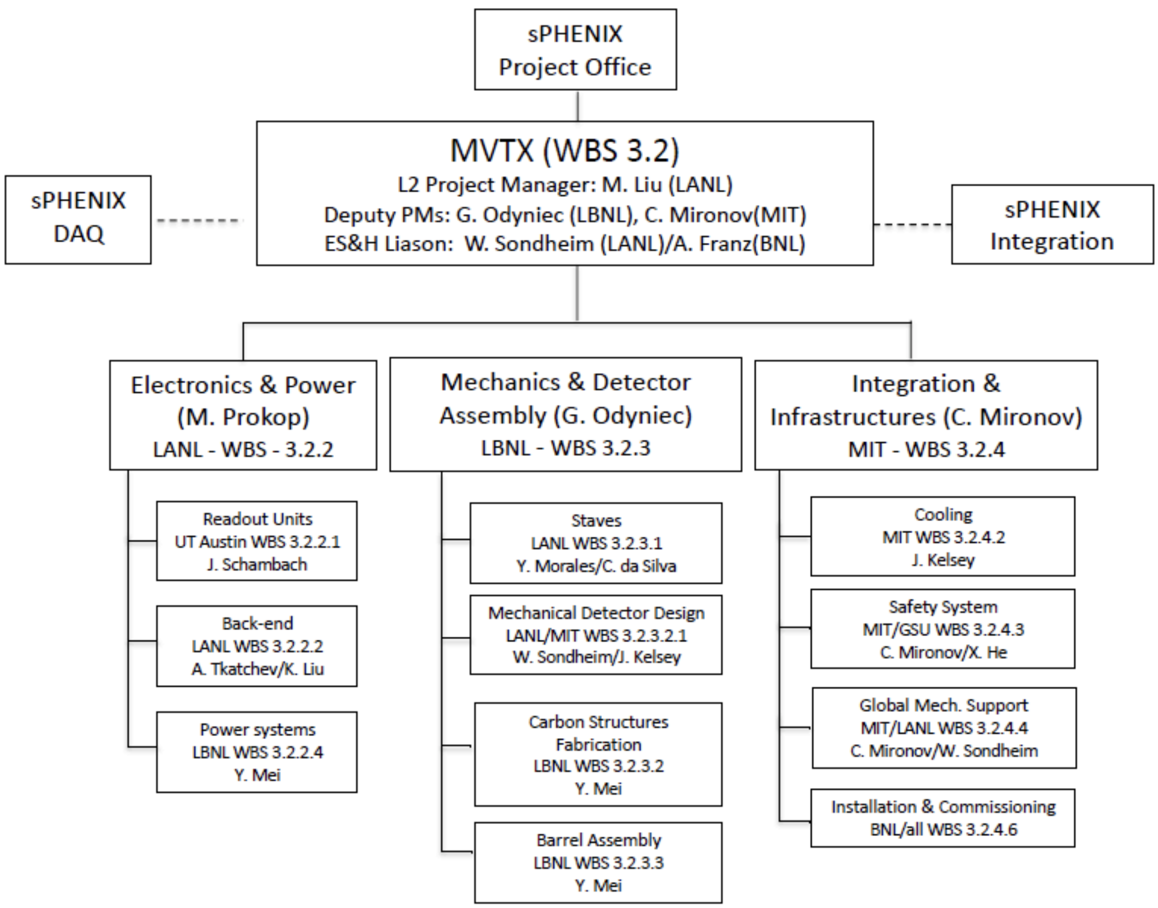
If the change is approved, PM is responsible for implementing the approved cost, budget, schedule or milestone changes in the official MVTX documents. If approval is denied, no changes are made to project documents. All PCRs, approved or rejected, are maintained in the document repository.

	NPP Associate Lab Director (level 1)	BNL-PO Ass. Chair (level 2)	MVTX Project Manager (Level 3)
Technical Baseline	Any change to technical scope that could adversely affect the science scope	Change to any WBS element that does not affect overall technical scope, but could impact initial performance	N/A
Cost	Any increase to the MVTX accumulated allocation of more than $400k contingency	Increase to any WBS element level 2 or allocation of between $200k and $400k contingency.	Increase to any WBS element level 3 or allocation of contingency up to $200k.
Schedule	Any delay of the anticipated completion date	Delay over 3 months of any milestone	Delay over 1 month of any milestone

3 MANAGEMENT STRUCTURE

3.1 Management Structure and Team

The management structure of the MVTX project is shown in the following organization chart.



3.2 Management Responsibilities.

The sPHENIX Project Office provides the primary oversite of the MVTX project.

- Ultimately responsible and accountable to the BNL for executing the Project within scope, cost and schedule in a safe and responsible manner.
- Provides access to laboratory/contractor resources, systems, and capabilities required to execute the Project.

MVTX Project Manager (PM) has the responsibility and authority for delivering the project scope on schedule and within budget.

- Manages the execution of the project to ensure that the project is completed within approved cost, schedule and technical scope.
- Ensures that effective project management systems, cost controls and milestone schedules are developed, documented and implemented to assess project performance.
- Ensures that project activities are conducted in a safe and environmentally sound manner.
- Ensures ES&H responsibilities and requirements are integrated into the project.
- Oversees design, fabrication, installation, and construction. Represents the project in interactions with the DOE.
- Requests and coordinates internal and external peer reviews of the project.
- Responsible for risk evaluation and management in accordance with the risk management plan.
- Manages the interface and coordination of requirements with other sPHENIX projects.

MVTX Deputy Project Managers (DPM)

- Assists the PM in all matters relating to the MVTX Project, including the planning, procurement, disposition and accounting of resources, progress reports on project activities, ESSH/QA issues, and Risk Management. In the absence of the CPM, the DPM assumes the project management responsibilities.
- Coordinates the interface with the LBNL engineering division.

MVTX Subsystem Managers

- Report directly to the PM
- Responsible for the design, fabrication, assembly, and testing of their subsystem in accordance with the performance requirements.
- Provide a quarterly status reports on both technical progress and schedule.
- Participates in weekly management meetings

3.3 Participating Institutions and Responsibilities

Los Alamos National Laboratory (LANL) : Overall readout electronics and mechanical system integration, project management.

Brookhaven National Laboratory (BNL) : Global system integration and services, safety and monitoring, project management.

Lawrence Berkley National Laboratory (LBNL) : Carbon structure production, LV and HV power system, full detector assembly and test, project management.

Massachusetts Institute of Technology (MIT/Bates) : Global mechanical system integration and cooling.

Massachusetts Institute of Technology (MIT) : Stave assembly and test at CERN.

University of California at Los Angeles (UCLA) : Simulation and readout testing.

University of California at Riverside (UCR) : Detector assembly and test, simulations.

Central China Normal University (CCNU/China): MAPS chip and stave test at CERN and/or CCNU.

Charles University (CU/Czech) : MAPS stave production and QA.

University of Colorado (UCol) : *b*-jet simulations and future hardware.

Czech Technical University (CTU/Czech) : MAPS stave production and QA at CERN.

Florida State University (FSU) : Offline software and simulations.

Georgia State University (GSU) : Online software and trigger development.

Iowa State University (ISU) : Detector assembly and test, simulations.

National Central University (NCU/Taiwan)* : Stave assembly and test, simulations.

University of New Mexico (UNM) : Cabling & connectors.

New Mexico State University (NMSU) : Tracking algorithm and physics simulations.

Purdue University (PU): Detector assembly and test, simulations.

Univ. of Science and Technology of China (USTC/China) : MAPS chip and stave test, simulations.

Sun Yat-Sen University (SYSU/China) : MVTX detector and physics simulations.

University of Texas at Austin (UTA) : MVTX readout electronics integration, Readout Units production and test.

Yonsei University (YSU/Korea) : MAPS chip production QA, readout electronics test and simulations

4 PROJECT MANAGEMENT AND OVERSIGHT

4.1 Risk Management

Risk management is based on a graded approach in which levels of risk are assessed for project activities and elements. Assessments of technical, cost and schedule risks are conducted throughout the project lifecycle.

The MVTX risk management approach consists of a five-step process:

1. Identifying potential project risk – any member of MVTX team may identify a potential risk. The subproject (WBS level 2) managers are responsible for addressing the potential risks with the DPM or PM's concurrence.
2. Analyzing project risk - the probability of a project risk occurring will be evaluated together with the potential impact to the project's technical performance, cost and/or schedule baseline. Probability is assessed qualitatively (Low, Moderate, and High).
3. Planning for and developing risk abatement strategies.
4. Executing risk abatement strategies - abatement strategies differ according to the potential risk and its timing. Monitoring and tracking the results and revising risk abatement strategies - risk assignments are associated to specific WBS entries down to Level 3. This serves to emphasize the role of the Level 2 WBS manager in risk management. Risk information, including the probability and impact assessments and brief summaries of mitigation strategies, are stored in the MVTX risk registry.

   The risk management Plan can be found in Appendix C. The most important risks for the MVTX project are documented in the report on "Risk assessment of the MVTX upgrade".

4.2 Project reporting

The PM will lead quarterly cost and schedule reviews and report the results to the sPHENIX Project Office.

We will hold monthly phone calls with DOE-NP and provide them with Quarterly progress reports.

The standard BNL accounting system is the basis for collecting cost data, and the Control Account structure for the MVTX will separate costs according to the WBS elements. A direct one-to-one relationship will be established between each WBS element of Level 2 or lower with a separate control account in the BNL accounting system.

Technical performance will be monitored throughout the project to ensure conformance to approved functional requirements. Design reviews and performance tests of the completed systems will be used to ensure that the equipment meets the functional requirements.

4.3 Engineering and Technology Readiness

The project will assess engineering and technology readiness through design reviews, IPRs, and other independent technical reviews as required.

4.4 Quality Assurance and Configuration/Document Management

The project shall adopt in its entirety the BNL Quality Assurance Program maintained in the SBMS. This QA Program describes how the various BNL management system processes and functions provide a management approach that conforms to the basic requirements defined in DOE Order 414.1C, Quality Assurance. These requirements will include:

- Management criteria related to organizational structure, responsibilities, planning, scheduling, and cost control
- Training and qualifications of personnel
- Quality improvement
- Documentation and records
- Work processes
- Engineering and design
- Procurement
- Inspection and acceptance testing
- Assessment

The quality program embodies the concept of the “graded approach” i.e., the selection and application of appropriate technical and administrative controls to work activities, equipment and items commensurate with the associated environment, safety and health risks and programmatic impact. The graded approach does not allow internal or external requirements to be ignored or waived, but does allow the degree of controls, verification, and documentation to be varied in meeting requirements based on environment, safety and health risks and programmatic issues.

4.5 Operation Readiness Plan

To ensure that sPHENIX will be ready to operate with the new inner sectors and the associated electronics the constructing and testing plan includes time to achieve this goal.

The project plan includes sufficient time to develop prototype for the electronics readout, and checkout of these both with and without beam. This will first allow for test of the RU’s and FELIX on both half barrel’s instrumented with electronics before the final installation of all electronics for subsequent years. This also allows for development of any new online, offline code well ahead of the physics run.

4.6 ESSH Plans for Fabrication

The MVTX upgrade for sPHENIX will use the BNL Quality Assurance Program to identify and control hazards for all equipment and work at BNL for the MVTX. The project will prepare designs and work procedures and have them reviewed by the appropriate laboratory or department review committees. The equipment and work practices used at sPHENIX will be reviewed by the C-AD Experimental Safety Review Committee (ESRC). The installation will be covered under the rules and safeguards in place for work in the RHIC experimental halls and assembly area.

4.7 Project Closeout

Project closeout will begin when all equipment is ready for installation in the sPHENIX detector. A Closeout Report will be developed prior to the date that closeout is expected in order to demonstrate the fulfillment of the functional requirements and deliverables. The report will address the closure status of purchase orders, the expected total cost of the Project and the value of remaining contingency. The report will also explain when the Project is expected to close the control accounts and complete the financial closeout. BNL will hold a Project Closeout review to assess whether the deliverables and functional requirements have been met.

Appendix 1

MVTX Full Proposal (Feb. 2018).