# Review Documents Available on the Agenda Page

**https://indico.bnl.gov/event/6544/**

- MVTX BOE
- MVTX PMP
- sPHENIX/MVTX Risk Register
- MVTX P6 dump, w/ Gantt Chart
- MVTX full proposal
- RU acceptance QA plan
- Stave acceptance QA plan
- MVTX Pre-P6 WBS Dictionary

- MVTX C&S Review Charge

- Previous Review report
  - **BNL Director's Review 4/2019**

# Today's Presentations

1. Overview of the MVTX's Place in sPHENIX- Ed

2. MVTX Overview – Ming, #1-4
3. Cost & Schedule – Dave, #1-4
4. MVTX in sPHENIX P6 and Risk Registry – Irina, #2-4

5. MVTX mechanical design – Walt, #1-3
6. MVTX Service Barrel and Integration – Camelia, #1-3
7. MVTX Detector QA and Assembly – Yuan, #1-3

8. MVTX Readout – Jo, #1-3

9. R&D and Beam Test Results – Cameron, #1,2
10. Summary – Ming, #4

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Cost and Schedule Review of the sPHENIX vertex detector upgrade, MVTX

July 29-30, 2019

The purpose of this review is to assess the technical feasibility of the sPHENIX vertex detector upgrade, MVTX, within cost and schedule constraints, and to assess the risk the MVTX upgrade introduces to the overall sPHENIX program.

In carrying out this review, the review committee is requested to consider the following questions:

1) Are the costs of the project sufficiently well understood, and are all resources required to successfully complete the project fully identified?
2) Is the schedule of the project sufficiently well understood and matched to the plan for installation in FY22?
3) Are the project risks properly identified and appropriate mitigation strategies in place, including any risks to sPHENIX operations? Do the cost and schedule estimates include adequate contingency based on sound and reasonable risk analysis?
4) Is the Project Management Plan complete?

I very much appreciate your willingness to lend your time and expertise to this important process and look forward to receiving your assessment.

Berndt Mueller
Associate Laboratory Director for Nuclear and Particle Physics

# sPHENIX MVTX Cost and Schedule Review
# MVTX Overview

Ming Liu, LANL

July 29-30, 2019

BNL

# Outline

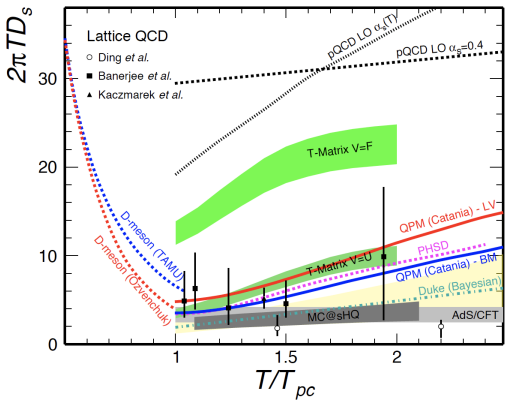
- Physics of MVTX
- Project scope, PMP
- Costs, schedules & risk register
- R&D highlights
- Previous review recommendations
- Issues and concerns

# MVTX Enables Exciting Science

- sPHENIX is the next flagship heavy ion physics experiment in the US (NSAC LRP2015)
  - **Jets**
  - **Upsilons**

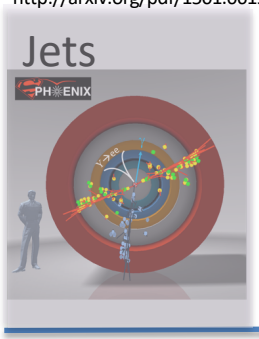
MVTX: Open heavy flavor physics – the 3rd physics pillar

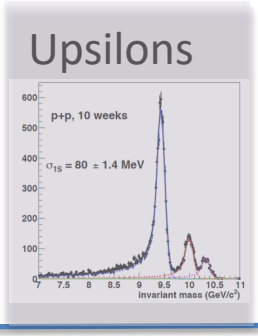
- **Precision study of the "inner workings of QGP"(LRP15)**
- **Quantitative determination of key parameters of QGP properties and interactions**

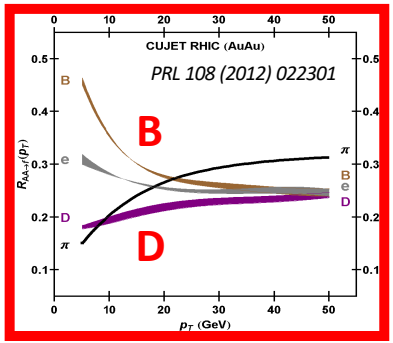



## sPHENIX 3 Physics Pillars

http://arxiv.org/pdf/1501.06197v1.pdf



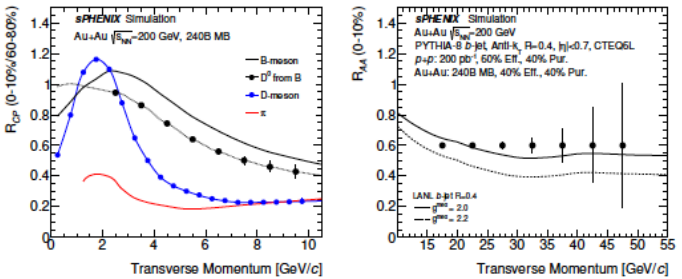
# The sPHENIX 3rd Science Pillar

Heavy quarks – unique probe of QGP w/ new scales, **$m_c$, $m_b$**

- Study mass dependence
  - **Jet quenching & energy loss**
  - **Flow – interaction with medium**

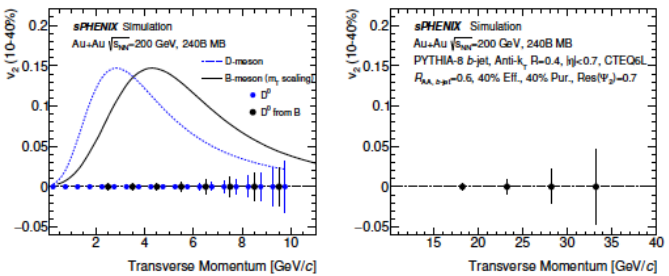
- Access QGP properties
  - **Temperature and momentum dependence of QGP transport parameters**

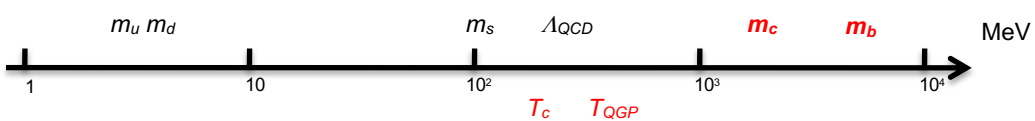
"B meson and b-jet modification"




From MVTX proposal

"B meson and b-jet flow"



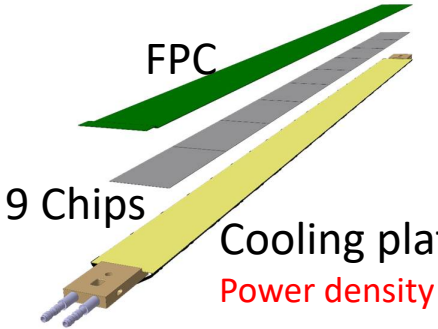



# Monolithic-Active-Pixel-Sensors (MAPS)

## The next Generation State of the Art Pixel Tracker

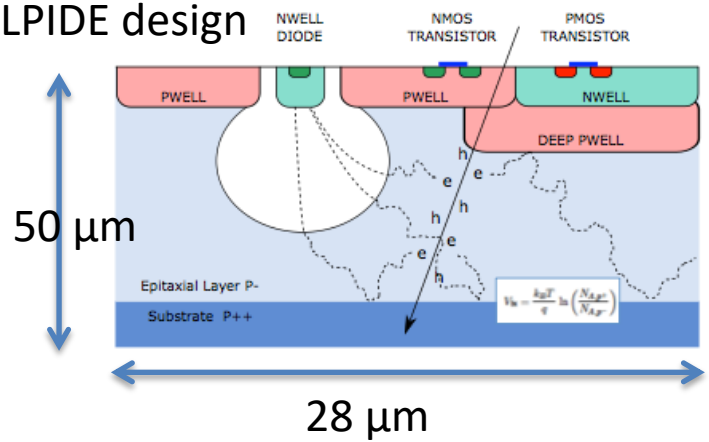
- Advantages of ALICE MAPS/ALPIDE:
  - **Very fine pitch (27x29 µm)**
  - **High efficiency (>99%) and low noise (<$10^{-6}$)**
  - **Time resolution, ~5 µs**
  - **Ultra-thin/low mass, 50µm (~0.3% $X_0$)**
  - **On-pixel digitization, low power dissipation**

An ideal detector for QGP physics!




A 9-chip MAPS stave, 1.5 x 27cm²

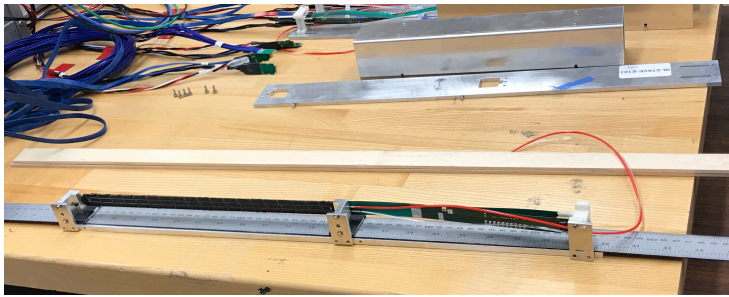
ALPIDE design




Tower Jazz 0.18 µm CMOS

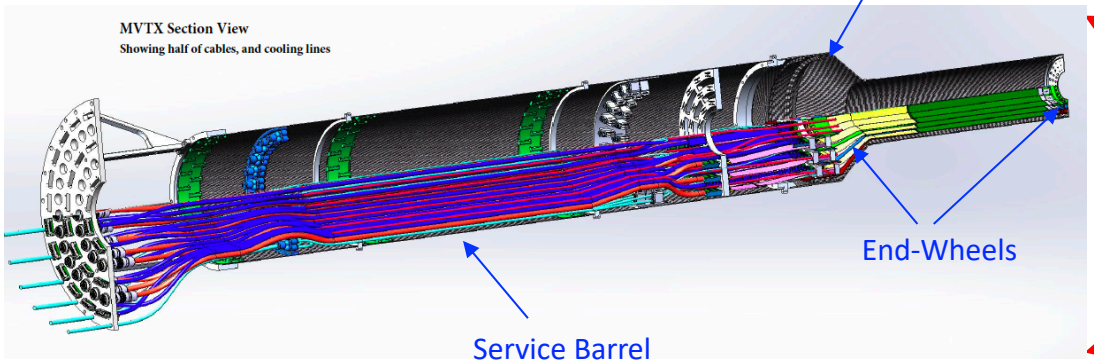
- feature size 180 nm
- metal layers 6
- gate oxide 3nm

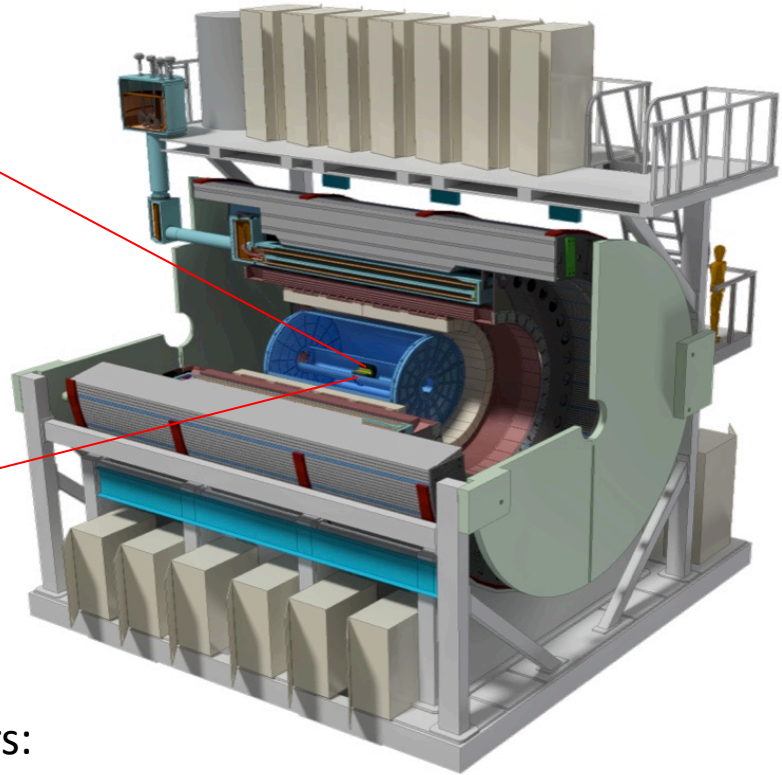
substrate: $N_A \sim 10^{18}$
epitaxial layer: $N_A \sim 10^{13}$
deep p-well: $N_A \sim 10^{16}$



# MVTX Detector – Modified from ALICE/ITS Design

- All electronics are “as built” by ALICE/ATLAS
- Modify the ALICE mechanics to fit it in sPHENIX

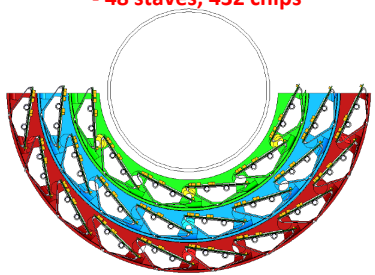


**MVTX parameters: L = 271 mm**

| | R_min (mm) |
|---|---|
| Layer 0 | 24.61 |
| Layer 1 | 31.98 |
| Layer 2 | 39.93 |

**3-layer sensor barrel**
**- 48 staves, 432 chips**



3 Layers:
12/16/20 staves

# Scope of the MVTX Project – WBS 3.02

- Mechanical system
  - **MVTX detector mechanical structures (3.02.03)**
    - **Design & simulations**
    - **End Wheels**
    - **Cylindrical support structure**
    - **Service barrels**

    Walt's talk

    Camelia's talk

    Status: Advanced CAD models
  - **Mechanical system integration (3.02.04)**
    - **Service barrel support & interface to sPHENIX**
    - **Installation tooling etc.**
    - **Adopt ALICE cooling parameters**
    - **Detector safety**

    Status: Advanced CAD models
  - **Detector assembly (3.02.03.03)**
    - **Stave QA & detector assembly @LBNL**

    Yuan's talk

    Status: Mature, following ITS
- Electronics (3.02.02)
  - **Readout Integration**

    Jo's talk
    - **RU QA & assembly @UT-A**
    - **Backend: ATLAS FELIX**
    - **FELIX boards @LANL/BNL**
    - **Frontend RU services: daughter cards, transition boards, cables etc.**
  - **Ancillary systems - "adopt" ALICE ITS system**
    - **Power, slow control & monitoring etc.**

  Status: Ready for production

BNL provides Staves & RUs, no cost to MVTX project:
- 84 ALICE/ITS-IB (modified) staves from CERN; 48+spares(2-inner layers+10%)
- 60 ALICE/ITS-RU from CERN 48+spares(12, 25%)

**Off-project**

Early R&D by LANL LDRD $5M, FY17-19

# MVTX Scope – WBS Summary

| 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 |

| WBS | Level 2 WBS Description | Burdened AY$ labor | Burdened AY$ M&S | Burdened AY$ Total |
|---|---|---|---|---|
| 3.02.01 | MVTX Project Management | $498.8k | $46.8k | $544.6k |
| 3.02.02 | MVTX Electronics | $211.2k | $358.4 | $569.6k |
| 3.02.03 | MVTX Mechanics and Detector Assembly | $1241.6k | $667.0K | $1908.6k |
| 3.02.04 | MVTX Integration and Installation | $456.8k | $416.5k | $873.3k |
| | Total | $2187.8k | $1500.6k | $3688.5k |

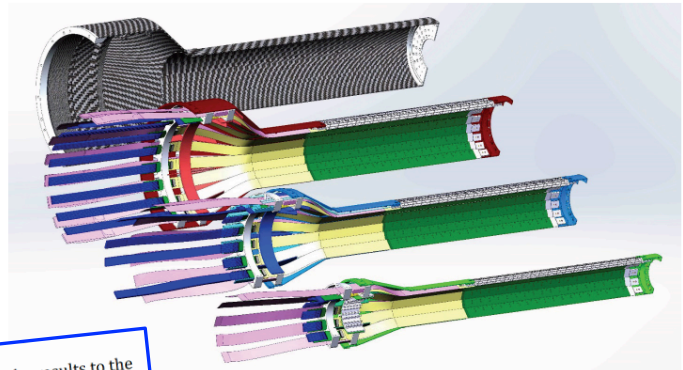
Major Challenge: Mechanical System

# Project Management Plan

- Draft PMP document completed
  - **Project baseline**
    - **Physics**
    - **Functional requirements/KPP**
    - **Technical scope**
    - **Cost breakdown**
    - **Schedule**
    - **Funding profile**
    - **Planned BNL funding**
    - **Baseline change control**
  - **Management structure**
    - **Organization and team**
    - **Management responsibilities**
    - **Participating institutions**
  - **Project management and oversight**
    - **Risk management**
    - **Project reporting**
    - **Engineering and technology readiness**
    - **Quality assurance and configuration/document management**
    - **Operation readiness plan**
    - **ESSH plans and fabrication**
    - **Project closeout**

**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.



**Management Plan**

**for**

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

**at the**

**Brookhaven National Laboratory**

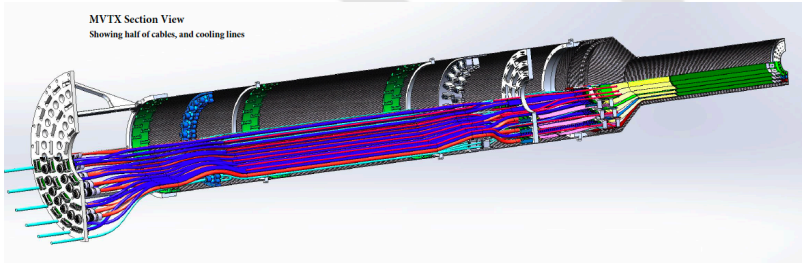
**July 26, 2019 (V7)**

- Project fully integrated into sPHENIX P6
  - **Costs, schedules and risk register**

# MVTX Deliverables in PMP

**Table 2 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 |




**Detectors + Services**

*: The staves and RUs are from BNL contribution, no cost to MVTX project.

# MVTX Performance Parameters: KPPs & UPPs

KPPs from MVTX PMP

**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 |

UPPs from MVTX PMP

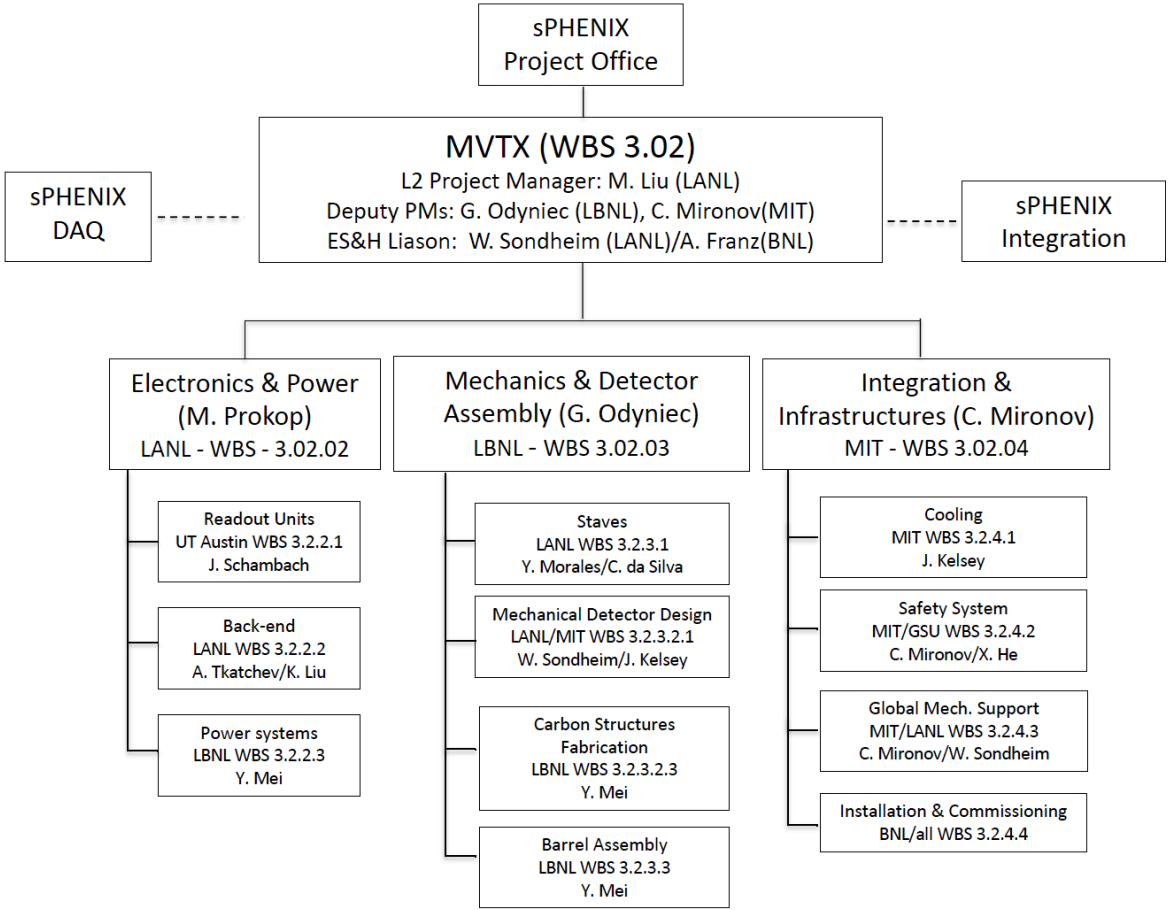
**Table 3. sPHENIX MVTX System Ultimate Performance Parameters (UPPs)**

| | |
|---|---|
| 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 |

# Baseline Change Control in PMP

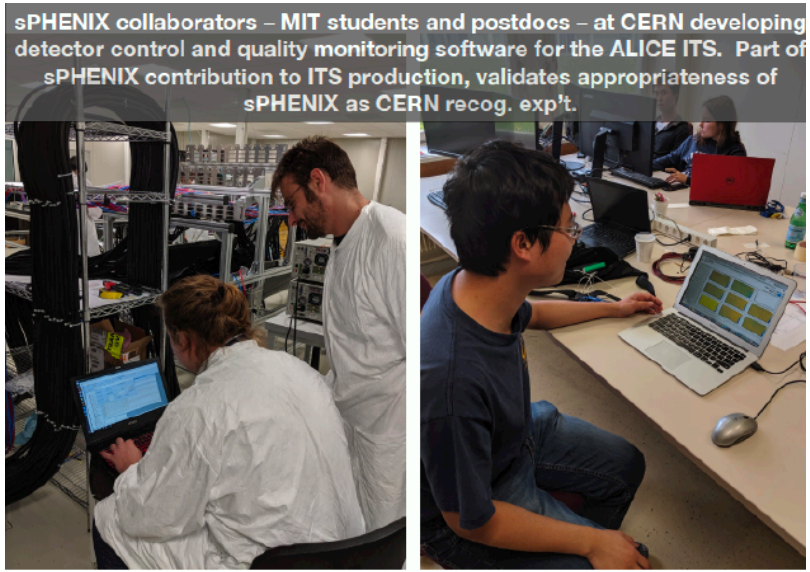
| | NPP Associate Lab Director (level 1) | BNL-PO Ass. Chair (level 2) | MVTX Project Manager (Level 3) |
|---|---|---|---|
| **Technical Baseline** | Any change to technical scope that could adversely affect the science scope | Change to any WBS element that does not affect overall technical scope, 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 |

# MVTX Organization Chart



# Collaborators & Responsibilities

22+ institutions and growing
- “MOU” through sPHENIX collaboration
- Active joint efforts with ALICE ITS group




**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.

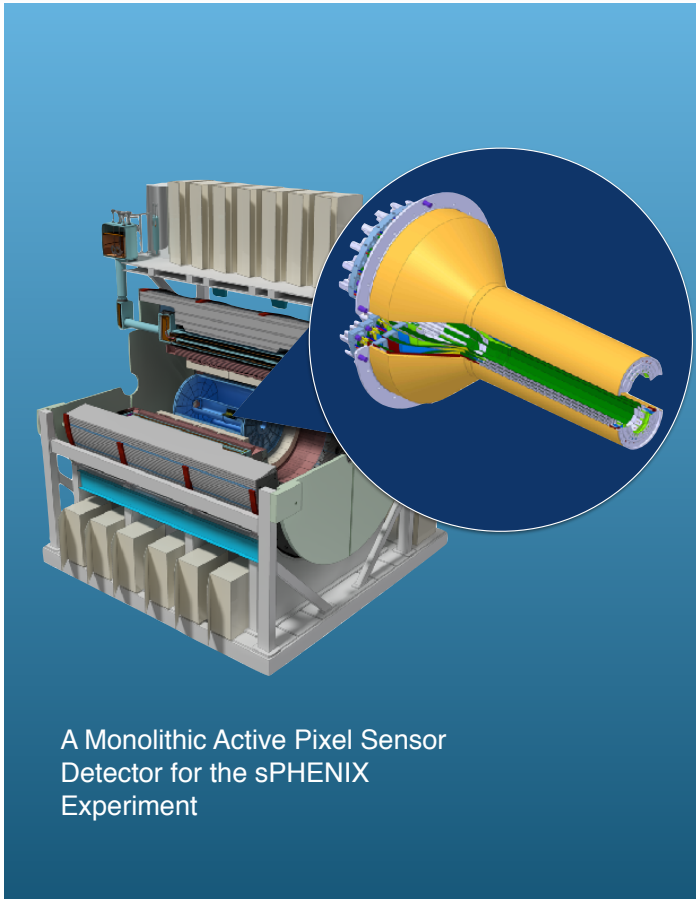
**Univ. of Science and Technology of China (USTC/China)** : MAPS chip and stave test, simulations.

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

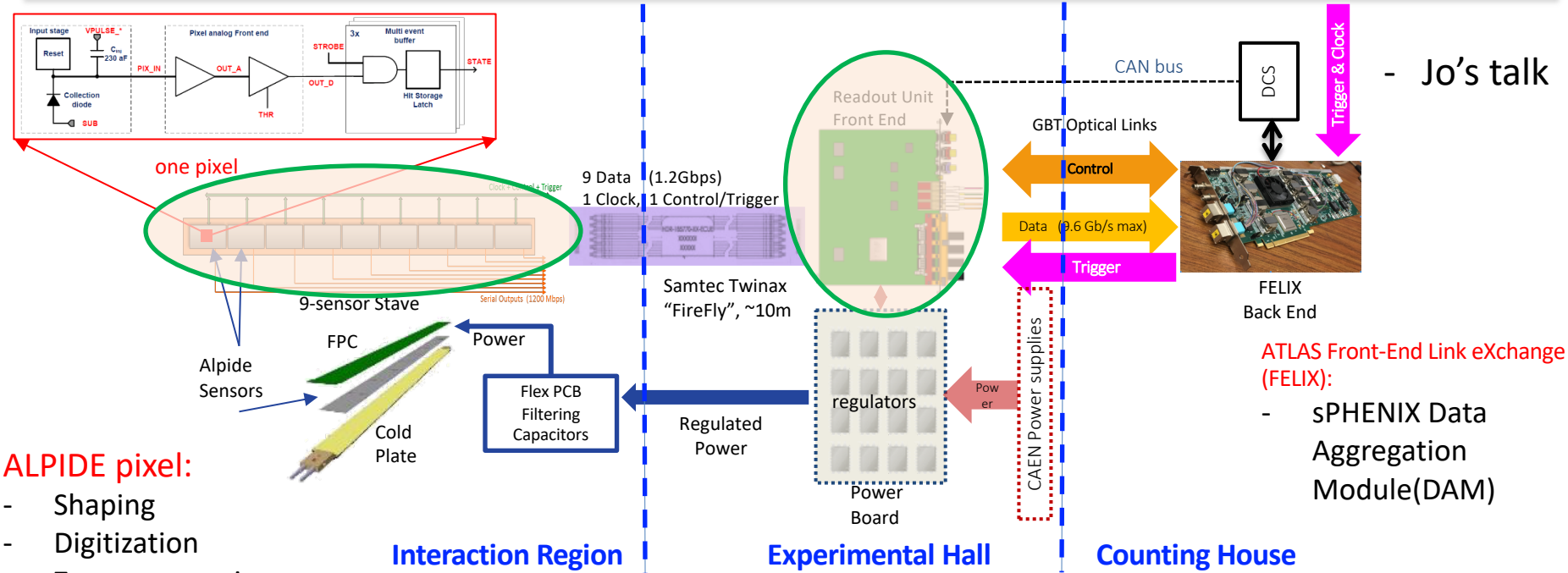
**University of Texas at Austin (UTA)** : MVTX readout electronics integration, Readout Units production and test.

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

# MVTX Detector, Cost & Schedule



# MVTX Readout, Power and Controls




- Jo's talk

ATLAS Front-End Link eXchange (FELIX):

- sPHENIX Data Aggregation Module(DAM)

ALPIDE pixel:

- Shaping
- Digitization
- Zero-suppression
- 3x buffer

MVTX Detector Electronics consists of three parts

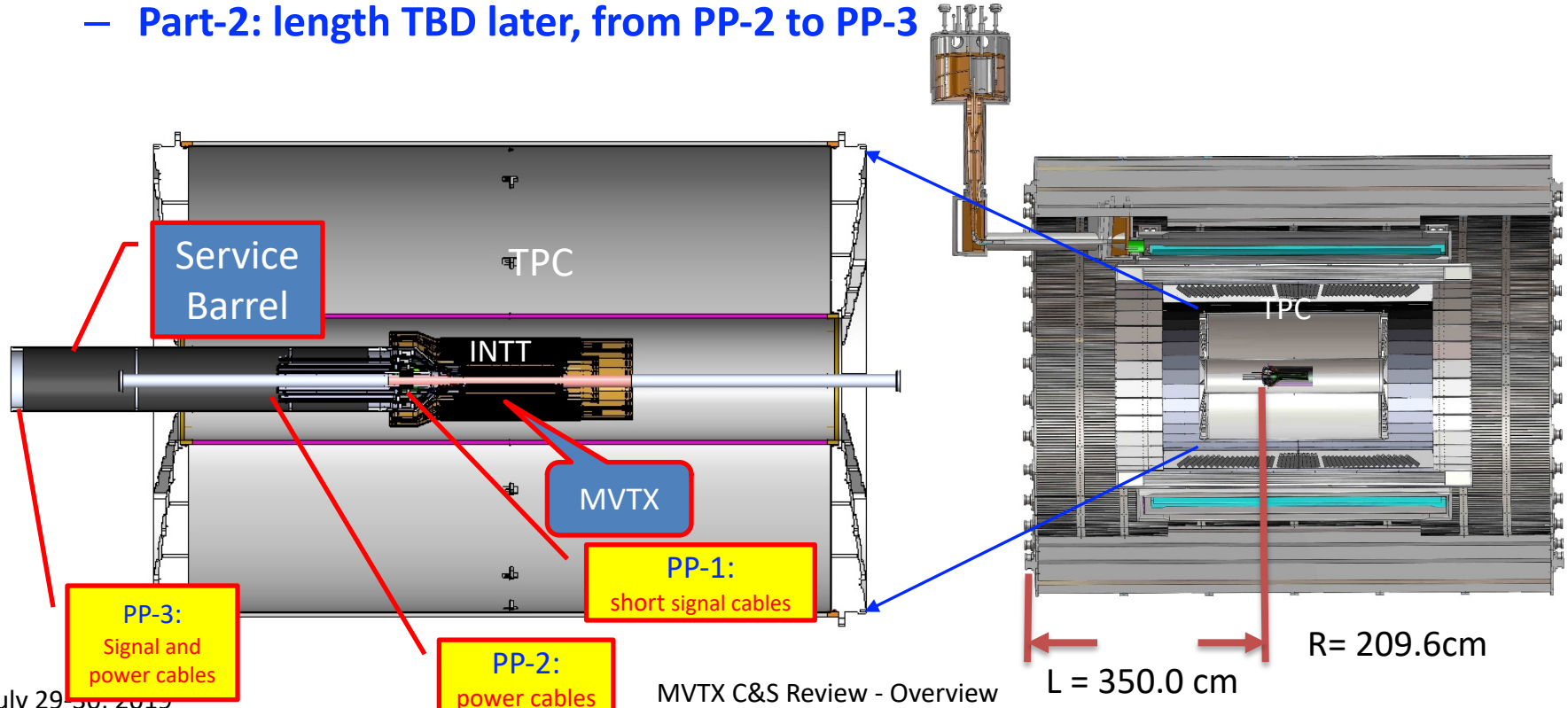
**Sensor**-Stave (9 ALPIDE chips) | **Front End**-Readout Unit | **Back End**-FELIX/DAM

(BNL provides staves and RUs, at no cost to MVTX project)

# MVTX Global Mechanical System Integration

- MVTX system preliminary design, with two parts:
  - **Part-1: from MVTX to PP-2, all power PCB, 40cm**
  - **Part-2: length TBD later, from PP-2 to PP-3**

Walt and Camelia' talks

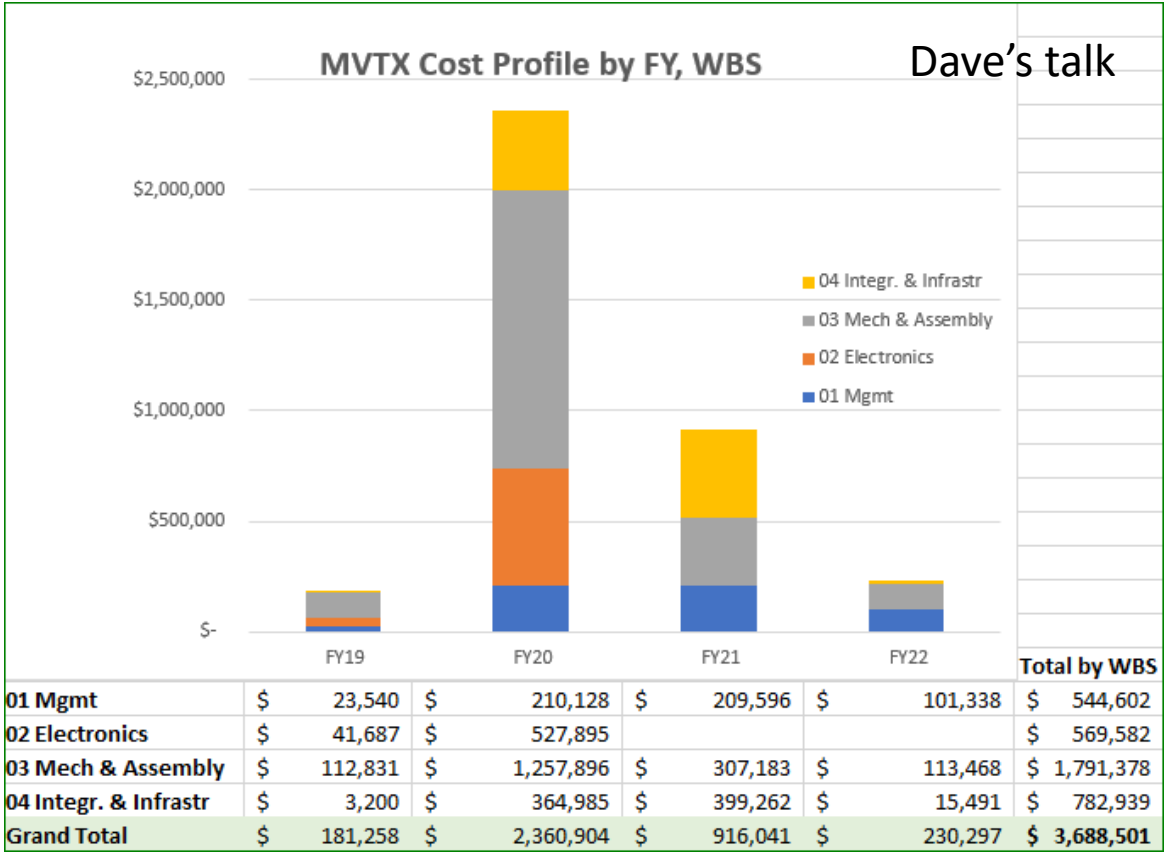


# Cost Drivers

Mechanical system:
- Detector carbon structures
- Service & integration

Electronics:
- Backend
- Power system

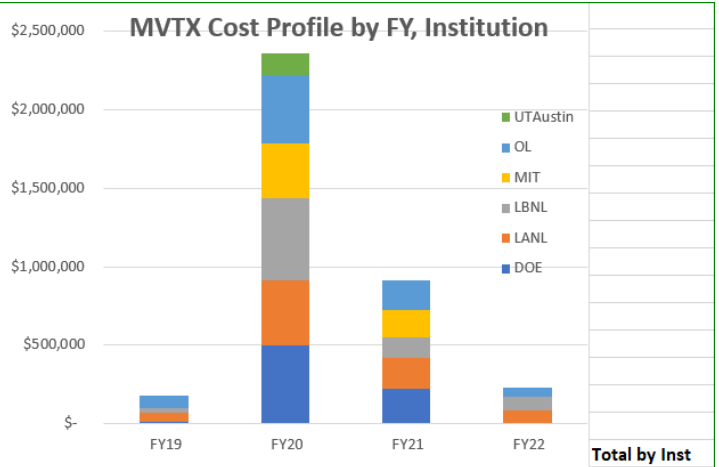
LANL LDRD for early R&D (off-project)
- $5M, FY17-19
- Readout integration
- Detector conceptual design
- Physics & simulations




| | | | | | 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** |

# Labor Profile in P6

Irina's talk




| | FY19 | FY20 | FY21 | FY22 | Total by Inst |
|---|---|---|---|---|---|
| DOE | $ 11,435 | $ 499,388 | $ 225,132 | | $ 735,955 |
| LANL | $ 57,174 | $ 410,884 | $ 196,591 | $ 88,073 | $ 752,722 |
| LBNL | $ 29,818 | $ 522,178 | $ 130,894 | $ 82,885 | $ 765,775 |
| MIT | | $ 355,287 | $ 173,797 | | $ 529,084 |
| OL | $ 82,831 | $ 432,912 | $ 189,628 | $ 59,339 | $ 764,710 |
| UTAustin | | $ 140,255 | | | $ 140,255 |
| **Grand Total** | **$ 181,258** | **$ 2,360,904** | **$ 916,041** | **$ 230,297** | **$3,688,501** |

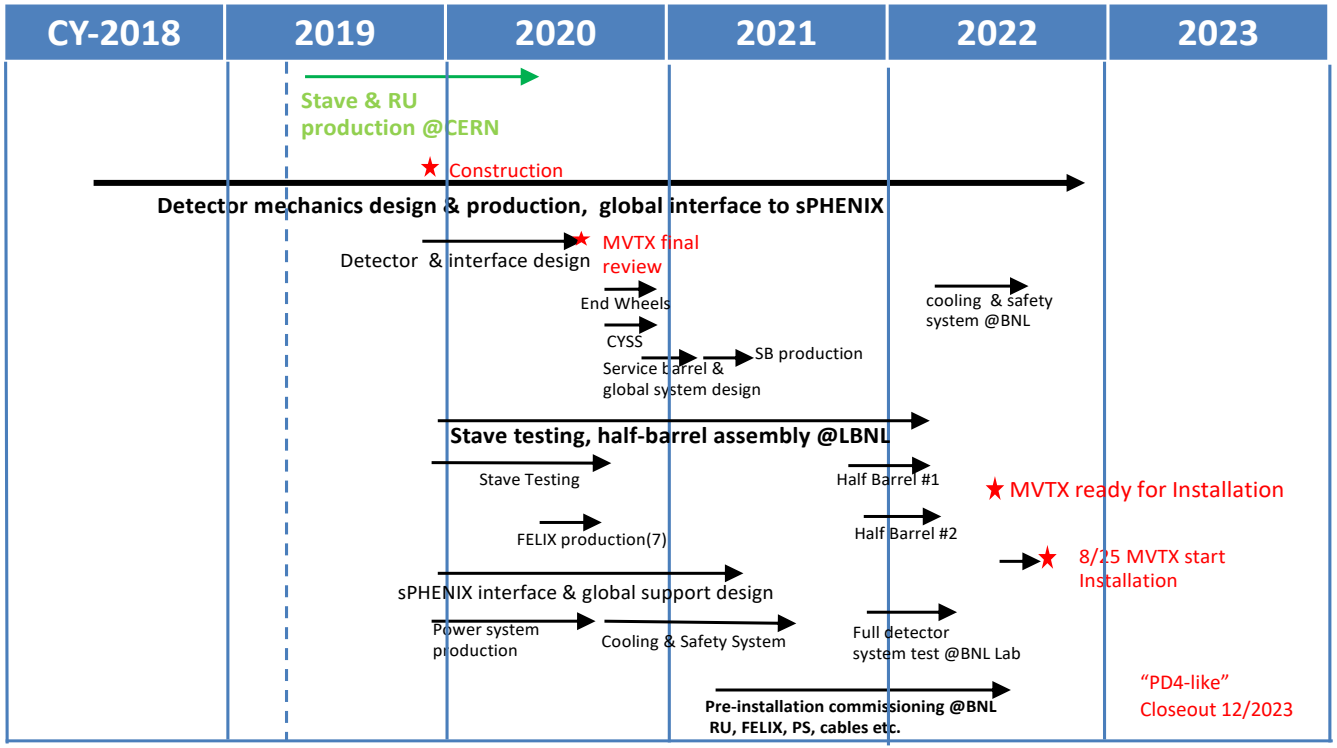
| | | FY19 | FY20 | FY21 | FY22 |
|---|---|---|---|---|---|
| LANL | MGR LANL | 0.02 | 0.28 | 0.28 | 0.12 |
| | PROF4 LANL | 0.08 | 0.43 | 0.07 | 0.03 |
| | SCI3 LANL | 0.06 | 1.01 | 0.00 | 0.27 |
| | TECH4 LANL | 0.00 | 0.04 | 0.00 | 0.00 |
| LBNL | CMMTECH4 LBNL | 0.00 | 0.00 | 0.04 | 0.09 |
| | ELENG3 LBNL | 0.00 | 0.06 | 0.08 | 0.03 |
| | ELTECH4 LBNL | 0.07 | 0.22 | 0.15 | 0.02 |
| | GRSTUD LBNL | 0.00 | 0.22 | 0.74 | 0.34 |
| | MECHENG3 LBNL | 0.00 | 0.02 | 0.15 | 0.06 |
| | MECHENG4 LBNL | 0.02 | 0.67 | 0.01 | 0.03 |
| | MECHTECH4 LBNL | 0.02 | 0.68 | 0.04 | 0.05 |
| | POSTD LBNL | 0.17 | 0.41 | 1.04 | 0.66 |
| | STAFFPHYS LBNL | 0.02 | 0.37 | 0.49 | 0.32 |
| MIT | PROF4 MIT | 0.00 | 1.11 | 0.43 | 0.00 |
| | SCI3 MIT | 0.00 | 0.00 | 0.03 | 0.00 |
| | TECH4 MIT | 0.00 | 0.08 | 0.21 | 0.00 |
| UTAustin | ElectEng UTAustin | 0.00 | 0.23 | 0.00 | 0.00 |
| | ElectTech UTAustin | 0.00 | 0.41 | 0.00 | 0.00 |

# Schedules & Milestones

Dave & Irina's talks

- Schedule drivers
  - Day-1 physics
  - CERN production
  - Carbon structures
- Early R&D by LANL LDRD

**Fully aligned with sPHENIX via external milestones**



# Risk Register

| Risk Identification | | | | Primary Risk (Unmitigated Risk Assessment) | | | | | | | | | | Risk Handling Plan (Mitigations) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Risk ID Number | RLS activity or next WBS | Owner | Risk Title | Schedule Impact | Technical Impact | Cost Impact Estimate ($K) | Probability Score (1-4) | Cost Score (1-4) | Schedule Score (1-4) | Technical Score (1-4) | Overall Impact Score | EMV K$ | Overall Impact Score | Risk Handling Plan (Mitigations) |
| MVTX_001 | 3.1.5 | M. Liu | Stave Delivery Delay | Low | | 0 | 2 | 0 | 2 | 0 | 1.33 | 0.00 | Low | Participate in stave production to be aware of possible delays. Assembly schedule could be compressed with additional manpower |
| MVTX_002 | 2.1 | M. Liu | RU Delivery Delay | Negligible | | 0 | 2 | 0 | 1 | 0 | 0.67 | 0.00 | Negligible | Large float in schedule before RUs are critical path |
| MVTX_003 | 2.2 | M. Liu | FELIX delivery Delay | Negligible | | 10 | 2 | 1 | 1 | 0 | 1.33 | 1.00 | Low | Large float in schedule before FELIX boards are critical path. |
| MVTX_004 | 2.3 | M. Liu | Samtec Cable R&D | Negligible | Low | 10 | 0 | 1 | 1 | 2 | 0.00 | 0.00 | Retired | Early R&D, ITS already uses 32 AWG custom cable at 8m. |
| MVTX_005 | 2.3 | M. Liu | Samtec Cable Delivery | Negligible | | 10 | 2 | 1 | 1 | 0 | 1.33 | 1.00 | Low | Large float in schedule before cabling of assembled detector is critical path |
| MVTX_006 | 2.3 | M. Liu | Custom Power Cable Unavailable | Low | | 20 | 3 | 1 | 2 | 0 | 3.00 | 6.00 | Moderate | Early involvement in ITS cable production to maximize advance notice |
| MVTX_007 | 2.3 | M. Liu | Power System Radiation | Low | | 20 | 3 | 1 | 2 | 0 | 3.00 | 3.00 | Moderate | Purchase additional radiation hard power modules from CAEN. Already procured control unit is needed in this scenario. 'Harsh environment' tolerant crate already exists at LANL and can be used. |
| MVTX_008 | 2 | M. Liu | lower yield in purchased electronics boards | Low | | 20 | 3 | 1 | 2 | 0 | 3.00 | 6.00 | Moderate | Reserve contingency to cover possible additional boards. early procurement and testing to mitigate schedule impacts. |
| MVTX_009 | 3.2 | M. Liu | Carbon Structure Cost | Low | | 20 | 3 | 1 | 2 | 0 | 3.00 | 6.00 | Moderate | Producing low-cost prototypes from outside vendors to validate other options |
| MVTX_010 | 3.2.3 | M. Liu | Carbon Structure Delivery Delay | Low | | 20 | 3 | 1 | 2 | 0 | 3.00 | 6.00 | Moderate | Stay in contact with other vendors. |
| MVTX_011 | 3.2.2 | M. Liu | Spiderwheel Design | Low | | 20 | 3 | 1 | 2 | 0 | 3.00 | 6.00 | Moderate | Conical design is essentially complete but would be produced by outside vendors to stay on cost. Strut design would need further development |
| MVTX_012 | 3.2.2 | M. Liu | Inner Support Material | Negligible | | 0 | 3 | 0 | 1 | 0 | 1.00 | 0.00 | Negligible | Most parts of concern are planar and can be produced with CF if necessary. These elements are a small component of total CF cost. |
| MVTX_013 | 3 | M. Liu | Half-Barrel Assembly | Moderate | | 20 | 2 | 1 | 3 | 0 | 2.67 | 2.00 | Moderate | Personnel trained in ALICE ITS assembly to reduce risk. Practice assembly with dummy or sacrificial parts first. |
| MVTX_014 | 3.3 | M. Liu | Installation | Moderate | | 10 | 2 | 1 | 3 | 0 | 2.67 | 1.00 | Moderate | Practice (dry run) installation with dummy or sacrificial parts. Installation scheme designed with non-administrative device safety in mind. Significant number of spare staves can replace any damaged ones. |
| MVTX_015 | 4.4 | M. Liu | Clam shell insertiion redesign | High | | 40 | 2 | 2 | 4 | 0 | 4.00 | 4.00 | High | Developed alternate insertion schemes with OSI. Discuss with C-AD to get advance warning. Seek quotes for new beampipe. |
| MVTX_016 | MVTX | M. Liu | Currency fluctuations | Negligible | | 20 | 3 | 1 | 1 | 0 | 2.00 | 3.00 | Low | Reserve contingency to cover possible fluctuations |
| MVTX_017 | 3 | M. Liu | Integration of slow controls, configuration and software/firmware into SPHENIX environment | Low | | 10 | 3 | 1 | 2 | 0 | 3.00 | 3.00 | Moderate | Early efforts with prototypes of full chain of complete system to test full needed functionality to mitigate schedule concerns. a moderate increase in contingency to cover any additional needed hardware for integrate. |
| MVTX_018 | 3 | M. Liu | Wirebonds not encapsulated | Low | Negligible | 20 | 2 | 1 | 2 | 1 | 2.67 | 2.00 | Moderate | Use triple bonds, dedicated transportation plates |
| MVTX_019 | 3 | M. Liu | End Wheel Redesign | Low | | 200 | 2 | 3 | 2 | 0 | 3.33 | 20.00 | High | Review current design, reserve contingency. |
| | | | | | | | | | | | | **70.00** | | |

# Project Status & Highlights

- Tested full stave readout chain with the final electronics at Fermilab Test Beam
  - **Tested long SamTec readout cables recently – last key detector integration R&D**
    **11.4m long cables, 10m desired**
- MVTX mechanical design: excellent progress
  - **Asked for quotes from outside companies based on preliminary designs**
  - **sPHENIX integration workfest held 7/10 @BNL, MVTX/INTT/TPC**
- Early R&D achieved through LANL LDRD, $5M, FY17-19
  - **Readout integration**
  - **Mechanical system conceptual design**
- Release of early BNL R&D fund in progress
  - **MVTX mechanical engineering design, MIT/LBNL**
- Project Management
  - **WBS, PMP, Risk Register updated**
  - **Fully integrated into sPHENIX P6, aligned with sPHENIX schedule**
  - **Will deliver MVTX on time and on budget under $5M**

**We are ready to start the project**

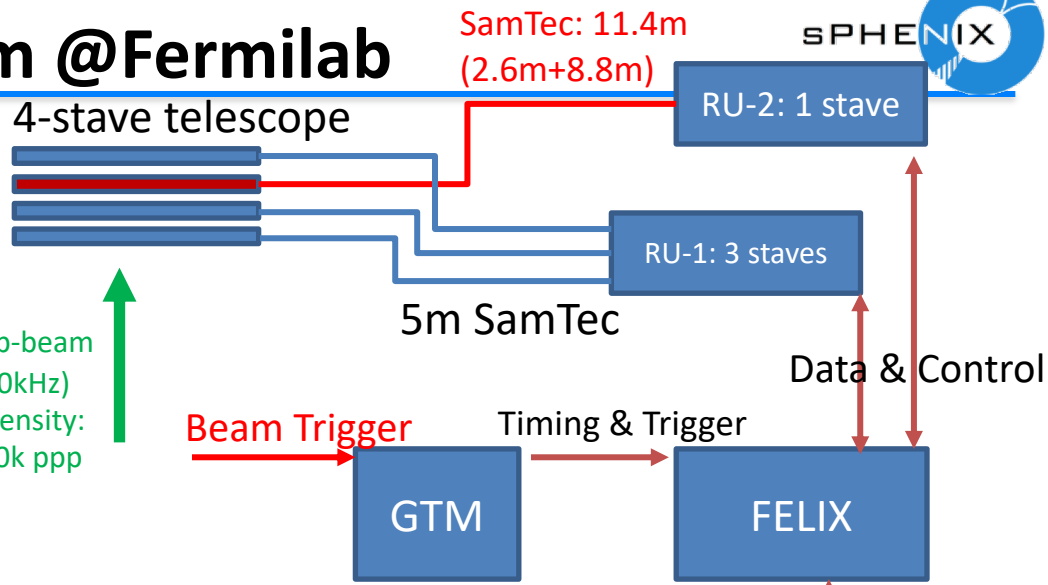
# Very Successful Test Beam @Fermilab

**5/20-25, 6/17-22, 2019**

- 4 staves
- 2 RUv1.1
- 1 PU
- 1 FELIX Server + RCDAQ
- sPHENIX GTM
- 11.4m Custom SamTec Cable
- Negative pressured cooling for staves

- 1 fully functioning 9-chip stave;
- 3 staves with a few broken sensors

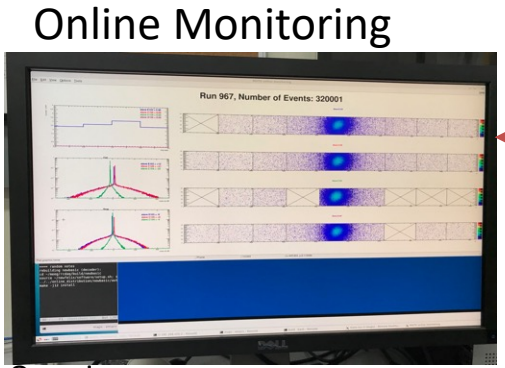
120GeV p-beam
10kHz (30kHz)
Beam intensity:
30k ~ 120k ppp




**A full system with final sensor/readout* hardware:**

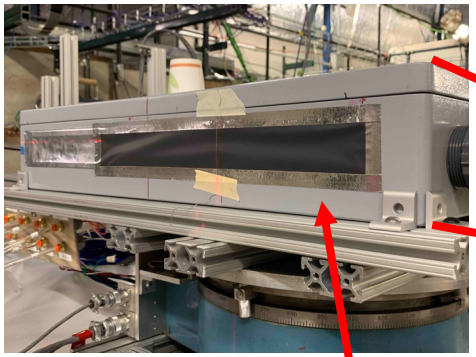
- Multi-Stave + Multi-RU -> FELIX readout demonstrated
- sPHENIX GTM integrated
- Long readout SamTec cable certified
- Cooling system demonstrated

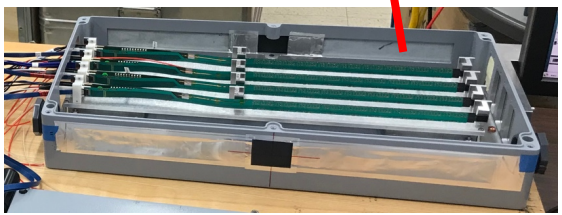
* RUv1.1 identical to the final RUv2 electrically

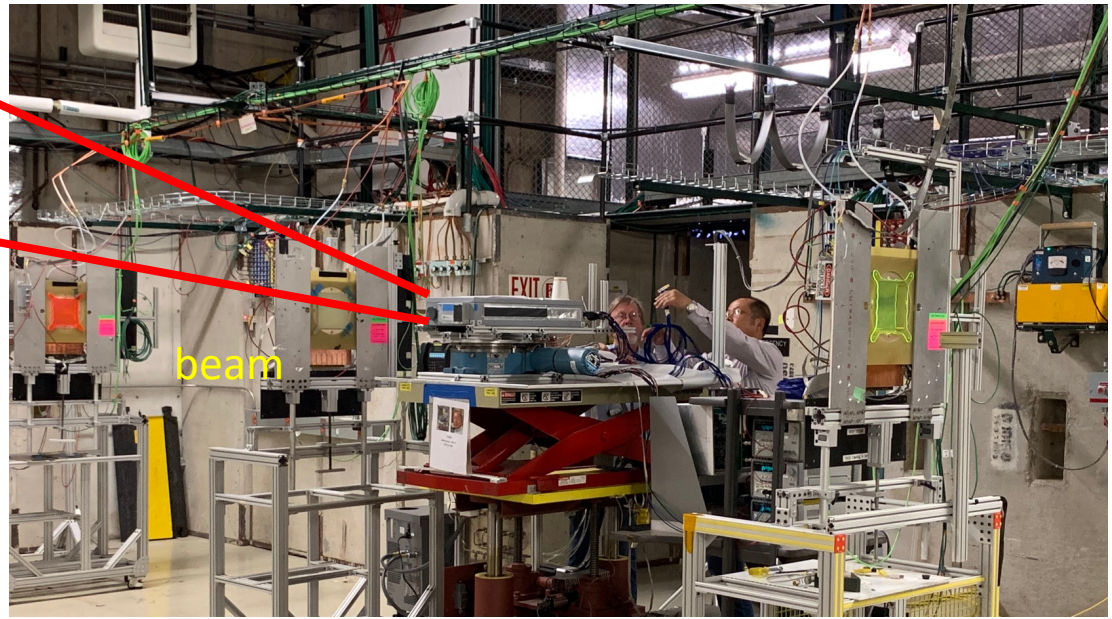


# 2019 MVTX Test Beam Setup @Fermilab

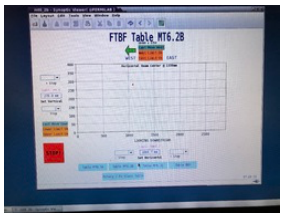
Cameron's talk








Stave housing sits on a motion table which can be moved in (x, y) plane perpendicular to the nominal beam direction. It can also be rotated (+40, -40) degrees (see photo on right). Operation was done at counting house.





# Recommendations from Last April Director's Review

(Review Report posted on the agenda page)

# Report from April BNL Director's PD2/3 Reviews: Silicon Detectors - MVTX, INTT (1)

**Silicon Detectors & Mechanical Integration** - Bill Wahl (BNL), Paul O'Connor (BNL), Sven Herrmann (BNL)

**Acknowledgements**

The sub-committee commends the INTT & MVTX detector projects for their state of technical readiness. The designs are very mature for a project at pre-PD1 and the decision to leverage experience from past projects will likely result in cost savings and significant risk reduction.

**Committee Response to Review Charge**

1. **Conceptual Design:** Is the conceptual design sound and likely to meet the project's technical performance requirements most efficiently and effectively?

   **Response: Yes.** Both detectors rely heavily on prior experiments, which is a wise and conservative strategy. Further work is needed, which is well understood by both detector projects as they work towards a final design.

2. **Project Scope:** Are the project's scope and specifications sufficiently defined to support the preliminary cost and schedule estimates? Are the interfaces with the sPHENIX MIE project and the Infrastructure and Facility Upgrade Project properly understood and documented?

   **Response: Yes (qualified).** The technical specifications for both detector projects are generally understood and well aligned with cost & schedule estimates. Better definition of flow-down requirements should be articulated by the project to best support science objectives. Both silicon detector projects appear to be working closely with the Office of System Integration (OSI) to establish and comply with interface requirements.

3. **Risks:** Are the project risks properly identified and appropriate mitigation strategies in place?

   **Response: No. For both detector projects,** a limited number of Risks have been identified, which the committee feels is unrealistic considering the scope and complexity of each project. The methodology for managing Risks is inconsistent with the rest of the project.

4. **Cost and Schedule:** Are the cost and schedule estimates credible and realistic for this stage of the project? Do they include adequate scope, cost, and schedule contingency?

   **Response: Yes (qualified).** Yes, for this stage of the project, but further work is needed to develop a defendable baseline. INTT contributed labor for management is not captured in the plan or BOE.

BNL Director's Review of sPHENIX 13 April 17, 2019

1. Yes. MVTX design is sound and will meet the requirements.
   - Readout electronics is ready for production;
   - Preliminary mechanical system design completed

2. Yes. MVTX project is fully integrated into sPHENIX P6.
   - Cost & Schedule, WBS, Risks register.
   - RLS fully aligned with sPHENIX via external milestones

   See Irina's talk

3. Yes. MVTX risk register integrated into sPHENIX Risks registry.

   See Irina's talk

4. Yes. MVTX project is fully integrated into sPHENIX P6,
   - MVTX baseline is define and PMP is completed.
   - RLS fully aligned with sPHENIX via external milestones

   See Dave and Irina's talks

# Report from April BNL Director's PD2/3 Reviews: Silicon Detectors - MVTX, INTT (2)

5. **Management:** Is the project being properly managed at this stage? Is the documentation appropriate at this stage of the project?

   **Response: Yes (qualified).** The committee says yes but only at this pre-PD1 stage. Further work is needed for both projects to develop the necessary management tools to be consistent with the rest of the project.

6. **ES&H:** Is ES&H being properly addressed given the project's current stage of development?

   **Response: Yes.** Planned usage of ES&H best practices were communicated by both silicon detector projects.

**Comments**

1. The MVTX staves are part of a common production at CERN for both ALICE and sPHENIX. Staves are produced in three performance grades ("gold", "silver", "bronze"). Both ALICE and sPHENIX plan to accept both gold and silver staves. However, the distribution of gold and silver staves has not been established for either project. The MVTX should specify the minimum acceptable number of gold staves to meet their tracking requirements.

2. A milestone master list and possibly a corresponding Milestone Dictionary for both projects should be made available for future reviews.

3. The WBS Dictionary and Critical Path for the MVTX & INTT should be posted to the PD2/3 review site ahead of the next review.

4. Detailed mock-ups for both silicon detectors should be constructed to minimize conflicts during integration (piping, cabling, support, etc.).

5. For both Silicon Detector projects, FTE requirements were not articulated in the presentations. At future reviews, it would be best to have a slide that speaks to FTE requirements by resource type.

**Issues & Concerns**

As a project, there appears to be a general reluctance to add risks to the Risk Registry. Known Risks should be included in the Registry, even those with a low probability. This approach will make it clear to future reviewers that Risk management is fully embraced by the project and risks are not being overlooked.

1. Silicon Detector Risks are being managed differently than the rest of the project. Early adoption of the standard format would be most appropriate.

BNL Director's Review of sPHENIX 14 April 17, 2019

5. Yes. MVTX is fully integrated into sPHENIX P6, and PMP completed
6. Yes. ES&H document completed.

1. sPHENIX follows the same ITS/IB stave QA Gold/Silver standard (about 50-50 for ITS/IB); Latest production had higher yield of gold, ~>70%

2. MVTX is fully integrated into sPHENIX P6, a list of milestones and critical paths are identified in P6.
   - Irina's talk

3. Pre-P6 MVTX WBS Dictionary was produced based on MS Project file that is used to integrate MVTX into the sPHENIX P6. Latest MVTX WBS and Critical paths are in P6. WBS Dictionary will be updated after this review.
   - Irina's talk

4. Detailed 3-D mockup was built and used to develop the MVTX mechanical design.
   - Walt's talk

5. MVTX is fully integrated into sPHENIX P6, cost and labor profiles are in P6
   - Dave and Irina's talks

1. MVTX Risk Register is fully integrated into sPHENIX,
   - Irina's talk

# Report from April BNL Director's PD2/3 Reviews: Silicon Detectors - MVTX, INTT (3)

2. For the MVTX, there needs to be better alignment between the spending and funding profile as they are currently out of phase. In fact, activities such as Stave testing are currently delayed due to the unavailability of funds.
3. It appears that work on MVTX has started at institutions with the expectation that payment will be made after the fact. It is not clear what agreements are in place that would authorize the start of work.
4. Resources for MVTX software development are not represented in the schedule. Planning is underway, but it is important to finalize resource needs and include them in the plan as early as possible.
5. The MVTX project only has 6 months of float, which might not be enough, especially since some activities are already behind schedule due to funding availability.
6. The INTT project needs electrical engineering resources, which is not reflected in the current plan and still needs to be negotiated between BNL & RIKEN.
7. It is not clear if the INTT and MVTX projects will follow EV reporting. If they will, there are missing aspects of the plan that would need to be addressed prior to setting the baseline (labor hours on activities, timing of payments to vendors, etc.).
8. It appears the WBS Dictionary, BOE, and Risk Registry for both Silicon Detectors are not integrated into sPHENIX.
9. The MVTX project did not present documentation that suggests it is following the same PM methods as the other sPHENIX subsystems (WBS Dictionary, Primavera P6 format, etc.), which suggests it is not part of an integrated schedule.
10. Funding for INTT management activities is contributed by BNL but it is not identified in the plan.
11. The proposed design changes for the sPHENIX beampipe and beampipe support to accommodate the MVTX seems nontrivial and still requires buy-in. This Risk should be held at the project level and settled reasonably soon.
12. The INTT Flex bus extender is made from Liquid Crystal Polymer (LCP) instead of Polyimide due to its smaller loss tangent but LCP is a less mature technology and not as robust as Polyimide.

**Recommendations (1 & 2 to be completed prior to MIE PD-3. 3-11 to be completed by the end of the calendar year)**

1. Clearly articulate requirements flow-down and margin analysis during future plenary sessions. [Note: This would also be useful for the full sPHENIX scope as noted earlier in the report.]
2. Develop a clear methodology for performing verification/validation against specifications and interface requirements.
3. Develop a detailed set of key milestones to ensure the same level of rigor is applied relative to the MIE and Infrastructure/Facility parts of the project. (recommendation for MVTX & INTT)
4. Clearly document and communicate change control and configuration control methods at partnering institutions and the eventual roll-up to BNL. (recommendation for MVTX & INTT)

BNL Director's Review of sPHENIX 15 April 17, 2019

2. MVTX project RLS is fully integrated into sPHENIX P6, Dave and Irina's talks
3. BNL has agreed to provide early R&D fund to MIT and LBNL to support mechanical system early R&D design work.
4. Much of the MVTX software work is based on the common sPHENIX online and offline frameworks, work is mostly carried out by collaborators without cost to the MVTX project.
5. Based on current RLS, MVTX detector will be ready for installation in March 2022; MVTX is the last detector to go into IR (9/2022)

7. MVTX project reporting is in PMP.
   *"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."*
8. WBS, BOE and Risk Register are integrated into sPHENIX P6. Pre-P6 WBS Dictionary will be updated after this review.
9. MVTX project is integrated into sPHENIX P6, PMP developed.

11. Beam pipe modification is under discussion between sPHENIX Project Office and C-AD. This risk is in the MVTX/sPHENIX Risk Register.

1,2,3. MVTX is fully integrated into sPHENIX P6, milestone and critical paths identified in P6; same methodology used for MVTX

4. MVTX PMP completed, including change control and configuration control methods.

# Report from April BNL Director's PD2/3 Reviews: Silicon Detectors - MVTX, INTT (4)

5. Generate a list of early funding needs (similar to CD3a) to address near-term schedule delays that will be realized if funding doesn't become available. (recommendation for MVTX & INTT)
6. Enumerate all contributed labor and resources and establish commitment level from institutions by way of MOAs/MOUs (including management and software). (recommendation for MVTX & INTT)
7. Establish a clear policy for contingency at partnering institutions that are participating in the MVTX project (specifically contingency ownership & authority).
8. Generate a comprehensive list of Risks, which should be included in the Risk Registry. (recommendation for MVTX & INTT)
9. Establish the likelihood for metal particulate generation that can come in contact with wire bonds and pads and develop methods to protect them. (recommendation for MVTX)
10. Develop KPPs for the Silicon Detectors, which will establish the basis for determining project success. (recommendation for sPHENIX management)
11. Document and communicate the scientific need for both the silicon detectors. (general recommendation for sPHENIX)

5. MVTX early funding request submitted, and BNL has agreed to provide R&D fund to MIT and LBNL to carry out early R&D on mechanical structure design and fabrication estimate
6. Institution roles are defined in the PMP. "MOU" to be established through sPHENIX collaboration.
7. Contingency policy in PMP, BNL will own and oversee the spending of the project contingency.
8. MVTX risk register developed, integrated into the sPHENIX Risk Registry
9. MVTX project will follow exactly the same stave/sensor handling procedures developed by ITS for stave and detector assembly; no major issues found in ITS/IB project on this matter.
10. KPPs and UPPs are documented in MVTX PMP.
11. The MVTX science case is well documented in the MVXT full proposal. New developments are documented through sPHENIX physics and technical notes.

# Issues and Concerns

- Carbon structure production cost and schedule
  - **LBNL, other production activities/ATLAS**
  - **Explore other production sites, Italy, France, Korea, US …**
  - **High contingency in cost, ~40%**
- Mechanical system integration
  - **Potential clamp shell re-design for insertion - beampipe modification**
  - **High contingency in design cost, ~40%**

- Mitigations:
  - **Early R&D in mechanical design and fabrication to reduce uncertainties**
  - **Work with OSI on integration, following up closely with C-AD on the beampipe issue**

# Summary

- MVTX is ready to receive fund for the project
  - **Electrical system is ready for production**
  - **Preliminary detector mechanical design completed**
  - **Preliminary sPHENIX mechanical system integration developed**
- LANL LDRD support critical for early key R&D
- Costs, schedules and risk register integrated into sPHENIX P6, RLS aligned with sPHENIX
- Project management plan developed, TPC $4.6M, ready for installation on time for Day-1 physics

**We are ready to start the project!**

# Back Up & References

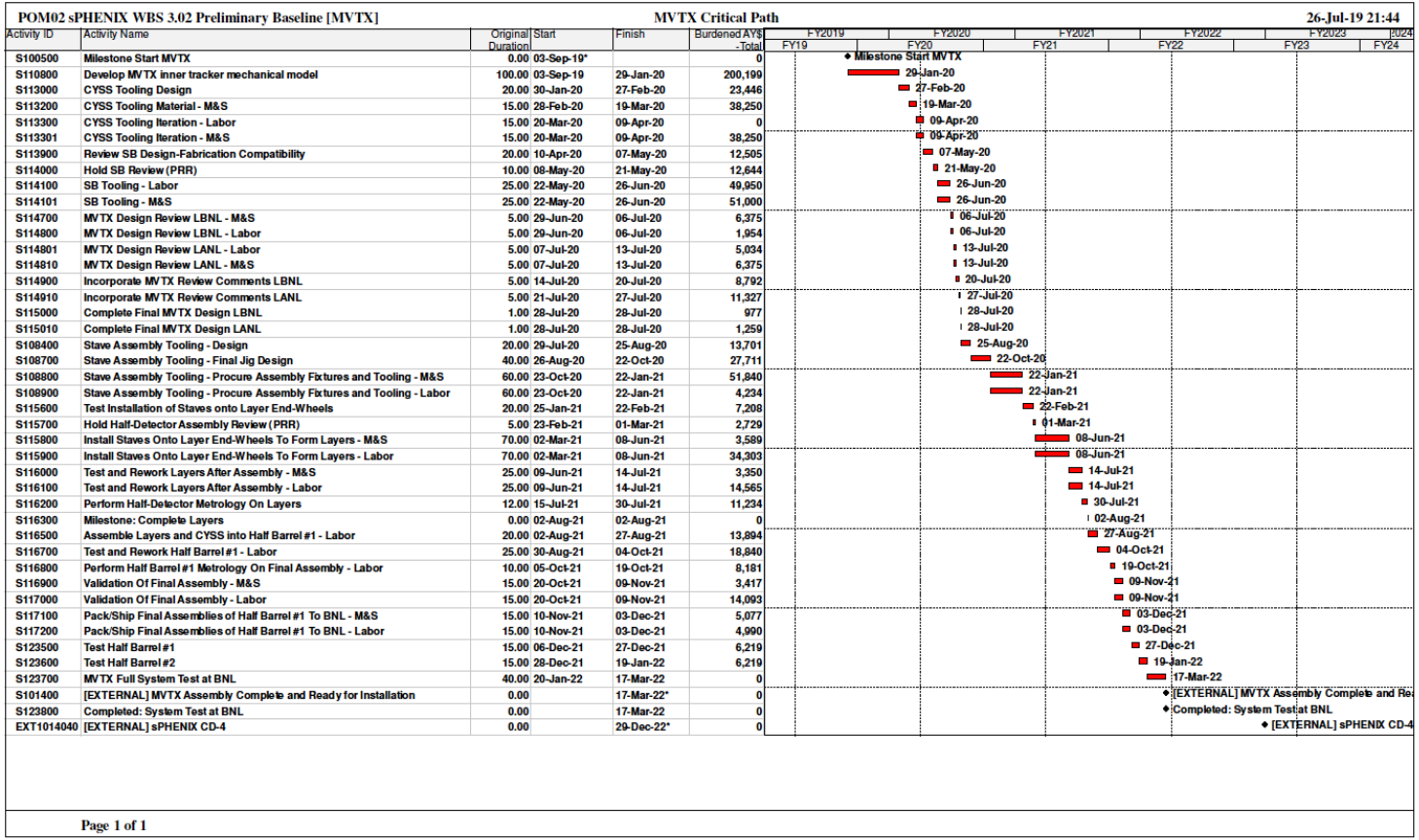
# Staves – QA plan

Tests run on sensors / staves

| Parameter | Gold | Silver | Bronze | Not working/ No back bias | |
|---|---|---|---|---|---|
| Iddd clocked | 500 to 850 mA | otherwise | - | -- | → Power Test |
| Idda clocked | 120 to 250 mA | otherwise | -- | -- | |
| Ibb @ 3V | Up to 10 mA | otherwise | -- | -- | |
| Max. bias voltage | 4V | -- | -- | Otherwise | |
| FIFO errors | 0 | -- | -- | Otherwise | → FIFO Test |
| FIFO exceptions | 0 | -- | -- | Otherwise | |
| Timeouts | 0 | - | - | Otherwise | → Digital Scan |
| Corrupt events | 0 | - | - | Otherwise | |
| Bad pixels per chip | < 50 | < 2100 | < 5243 | Otherwise | |
| Pixels without threshold per chip | < 5243 | < 26214 | < 52429 | Otherwise | → Threshold Scan |
| Dead pixels per chip | < 50 | < 2100 | < 5243 | Otherwise | |
| Average HIC noise | < 10 e | Otherwise | -- | -- | |
| Deviation of chip threshold | < 20% | < 30% | Otherwise | -- | |
| Threshold RMS | < 30 e | -- | Otherwise | -- | |
| Threshold RMS / Threshold mean | < 0.3 | -- | < 0.5 | Otherwise | |

Example for building ML/OL modules but the tests run are the same for all sensors

# Critical Path



POM02 sPHENIX WBS 3.02 Preliminary Baseline [MVTX] — MVTX Critical Path — 26-Jul-19 21:44

| Activity ID | Activity Name | Original Duration | Start | Finish | Burdened AY$ - Total |
|---|---|---|---|---|---|
| S100500 | Milestone Start MVTX | 0.00 | 03-Sep-19* | | 0 |
| S110800 | Develop MVTX inner tracker mechanical model | 100.00 | 03-Sep-19 | 29-Jan-20 | 200,199 |
| S113000 | CYSS Tooling Design | 20.00 | 30-Jan-20 | 27-Feb-20 | 23,446 |
| S113200 | CYSS Tooling Material - M&S | 15.00 | 28-Feb-20 | 19-Mar-20 | 38,250 |
| S113300 | CYSS Tooling Iteration - Labor | 15.00 | 20-Mar-20 | 09-Apr-20 | 0 |
| S113301 | CYSS Tooling Iteration - M&S | 15.00 | 20-Mar-20 | 09-Apr-20 | 38,250 |
| S113900 | Review SB Design-Fabrication Compatibility | 20.00 | 10-Apr-20 | 07-May-20 | 12,505 |
| S114000 | Hold SB Review (PRR) | 10.00 | 08-May-20 | 21-May-20 | 12,644 |
| S114100 | SB Tooling - Labor | 25.00 | 22-May-20 | 26-Jun-20 | 49,950 |
| S114101 | SB Tooling - M&S | 25.00 | 22-May-20 | 26-Jun-20 | 51,000 |
| S114700 | MVTX Design Review LBNL - M&S | 5.00 | 29-Jun-20 | 06-Jul-20 | 6,375 |
| S114800 | MVTX Design Review LBNL - Labor | 5.00 | 29-Jun-20 | 06-Jul-20 | 1,954 |
| S114801 | MVTX Design Review LANL - Labor | 5.00 | 07-Jul-20 | 13-Jul-20 | 5,034 |
| S114810 | MVTX Design Review LANL - M&S | 5.00 | 07-Jul-20 | 13-Jul-20 | 6,375 |
| S114900 | Incorporate MVTX Review Comments LBNL | 5.00 | 14-Jul-20 | 20-Jul-20 | 8,792 |
| S114910 | Incorporate MVTX Review Comments LANL | 5.00 | 21-Jul-20 | 27-Jul-20 | 11,327 |
| S115000 | Complete Final MVTX Design LBNL | 1.00 | 28-Jul-20 | 28-Jul-20 | 977 |
| S115010 | Complete Final MVTX Design LANL | 1.00 | 28-Jul-20 | 28-Jul-20 | 1,259 |
| S108400 | Stave Assembly Tooling - Design | 20.00 | 29-Jul-20 | 25-Aug-20 | 13,701 |
| S108700 | Stave Assembly Tooling - Final Jig Design | 40.00 | 26-Aug-20 | 22-Oct-20 | 27,711 |
| S108800 | Stave Assembly Tooling - Procure Assembly Fixtures and Tooling - M&S | 60.00 | 23-Oct-20 | 22-Jan-21 | 51,840 |
| S108900 | Stave Assembly Tooling - Procure Assembly Fixtures and Tooling - Labor | 60.00 | 23-Oct-20 | 22-Jan-21 | 4,234 |
| S115600 | Test Installation of Staves onto Layer End-Wheels | 20.00 | 25-Jan-21 | 22-Feb-21 | 7,208 |
| S115700 | Hold Half-Detector Assembly Review (PRR) | 5.00 | 23-Feb-21 | 01-Mar-21 | 2,729 |
| S115800 | Install Staves Onto Layer End-Wheels To Form Layers - M&S | 70.00 | 02-Mar-21 | 08-Jun-21 | 3,589 |
| S115900 | Install Staves Onto Layer End-Wheels To Form Layers - Labor | 70.00 | 02-Mar-21 | 08-Jun-21 | 34,303 |
| S116000 | Test and Rework Layers After Assembly - M&S | 25.00 | 09-Jun-21 | 14-Jul-21 | 3,350 |
| S116100 | Test and Rework Layers After Assembly - Labor | 25.00 | 09-Jun-21 | 14-Jul-21 | 14,565 |
| S116200 | Perform Half-Detector Metrology On Layers | 12.00 | 15-Jul-21 | 30-Jul-21 | 11,234 |
| S116300 | Milestone: Complete Layers | 0.00 | 02-Aug-21 | 02-Aug-21 | 0 |
| S116500 | Assemble Layers and CYSS into Half Barrel #1 - Labor | 20.00 | 02-Aug-21 | 27-Aug-21 | 13,894 |
| S116700 | Test and Rework Half Barrel #1 - Labor | 25.00 | 30-Aug-21 | 04-Oct-21 | 18,840 |
| S116800 | Perform Half Barrel #1 Metrology On Final Assembly - Labor | 10.00 | 05-Oct-21 | 19-Oct-21 | 8,181 |
| S116900 | Validation Of Final Assembly - M&S | 15.00 | 20-Oct-21 | 09-Nov-21 | 3,417 |
| S117000 | Validation Of Final Assembly - Labor | 15.00 | 20-Oct-21 | 09-Nov-21 | 14,093 |
| S117100 | Pack/Ship Final Assemblies of Half Barrel #1 To BNL - M&S | 15.00 | 10-Nov-21 | 03-Dec-21 | 5,077 |
| S117200 | Pack/Ship Final Assemblies of Half Barrel #1 To BNL - Labor | 15.00 | 10-Nov-21 | 03-Dec-21 | 4,990 |
| S123500 | Test Half Barrel #1 | 15.00 | 06-Dec-21 | 27-Dec-21 | 6,219 |
| S123600 | Test Half Barrel #2 | 15.00 | 28-Dec-21 | 19-Jan-22 | 6,219 |
| S123700 | MVTX Full System Test at BNL | 40.00 | 20-Jan-22 | 17-Mar-22 | 0 |
| S101400 | [EXTERNAL] MVTX Assembly Complete and Ready for Installation | 0.00 | | 17-Mar-22* | 0 |
| S123800 | Completed: System Test at BNL | 0.00 | | 17-Mar-22 | 0 |
| EXT1014040 | [EXTERNAL] sPHENIX CD-4 | 0.00 | | 29-Dec-22* | 0 |

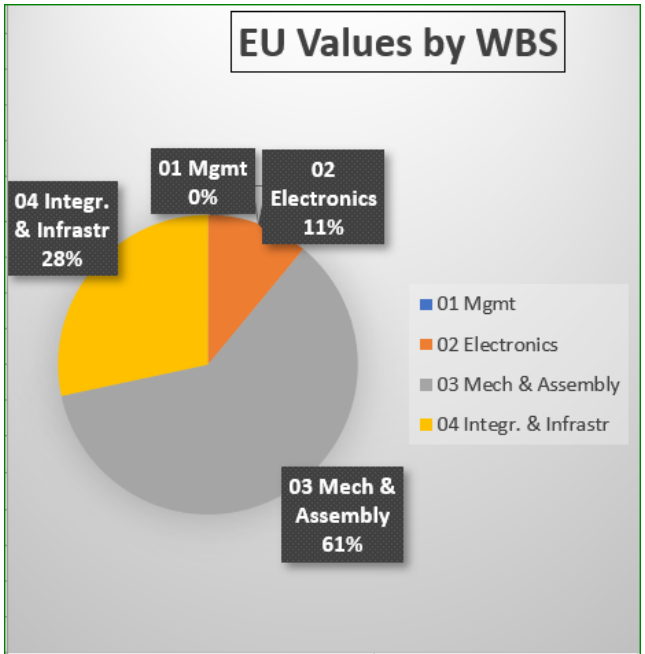


Page 1 of 1

# Estimate Uncertainty

EU tables are identical to those used by sPHENIX for establishing baseline cost

| **Labor** |
|---|
| L1 - Actual - 0% |
| L2 - Level of Effort Tasks - 5% |
| L3 - Advanced - 10% |
| L4 - Preliminary - 25% |
| L5 - Conceptual - 40% |
| L6 - Pre-conceptual - 60% |
| L7 - Rough Estimate - 80% |
| L8 - Beyond state of the art - 100% |
| **M&S** |
| M1 - Existing Purchase Order (Actual) - 0% |
| M2 - Travel, supplies, software - 5% |
| M3 - Advanced, Quote or Catalog Price - 10% |
| M4 - Preliminary Engineering Judgment - 25% |
| M5 - Conceptual Design - 40% |
| M6 - Pre-conceptual Design - 60% |
| M7 - Pre-conceptual - Uncommon work - 80% |
| M8 - Beyond state of the art - 100% |




| | | |
|---|---|---|
| **01 Mgmt** | **$** | **-** |
| **02 Electronics** | **$** | **101,642** |
| **03 Mech & Assembly** | **$** | **560,301** |
| **04 Integr. & Infrastr** | **$** | **262,053** |
| **Total EU** | **$** | **923,996** |

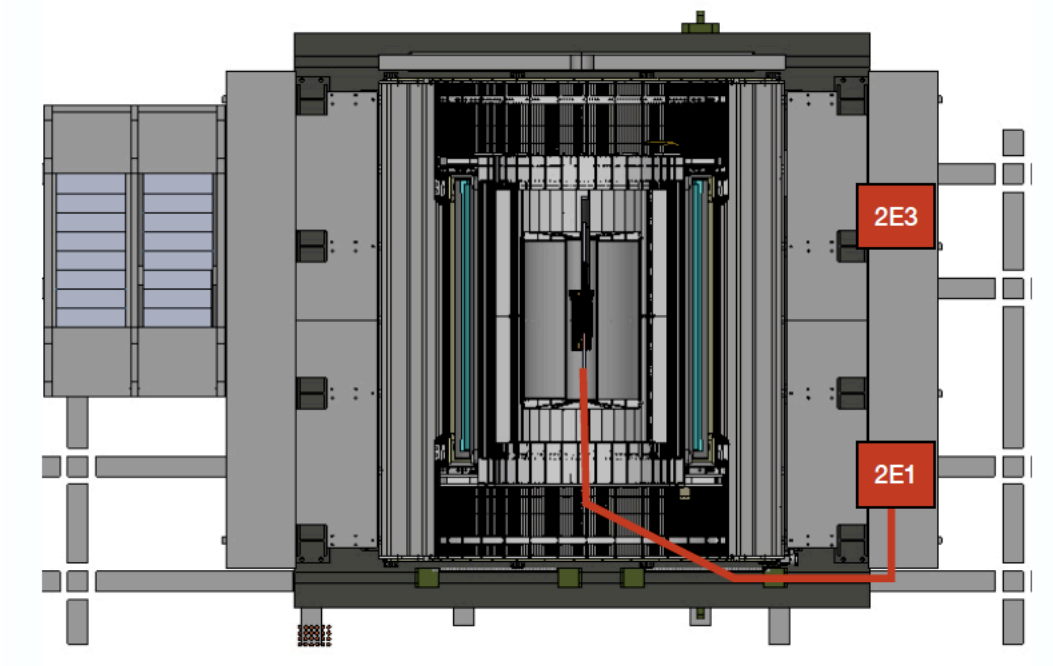
# Estimate Uncertainty by WBS

| WBS Name | Budgeted Cost | EU | EU Percent |
|---|---|---|---|
| MVTX Project Management | $ 544,602 | $ - | 0% |
| Readout Unit (RU) | $ 213,002 | $ 27,867 | 13% |
| FELIX 2.0 | $ 110,571 | $ 27,260 | 25% |
| Power Boards | $ 144,329 | $ 33,705 | 23% |
| Power Supplies | $ 101,680 | $ 12,809 | 13% |
| Production | $ 72,924 | $ 2,318 | 3% |
| Stave Assembly Tooling | $ 97,486 | $ 38,994 | 40% |
| Metrology | $ 75,834 | $ 27,480 | 36% |
| Shipping and Storage Containers | $ 63,926 | $ 6,393 | 10% |
| Shipping the Staves from CERN to LBNL | $ 30,600 | $ 3,060 | 10% |
| Mechanics Detector Design | $ 200,199 | $ 80,080 | 40% |
| End Wheels | $ 310,865 | $ 123,465 | 40% |
| Mechanics Fabrication | $ 90,160 | $ - | 0% |
| Cylindrical Support Structure (CYSS) | $ 200,808 | $ 80,323 | 40% |
| Service Barrel (SB) | $ 266,239 | $ 97,693 | 37% |
| MVTX Final Design Review | $ 42,093 | $ 7,213 | 17% |
| Assembly and Testing | $ 21,565 | $ 5,391 | 25% |
| Layer Assembly and Test | $ 76,978 | $ 29,836 | 39% |
| Half Barrel #1 Assembly and Test | $ 75,436 | $ 26,038 | 35% |
| Half Barrel #2 Assembly and Test | $ 75,859 | $ 26,207 | 35% |
| MVTX Integration and Infrastructure | $ 58,084 | $ 5,808 | 10% |
| Cooling System | $ 172,233 | $ 54,721 | 32% |
| Safety Systems | $ 151,940 | $ 37,743 | 25% |
| Service Barrel Support Frame & MVTX Interface to sPHENIX | $ 431,797 | $ 163,661 | 38% |
| Half detector Assembly Readout and Cooling Test at BNL | $ 59,290 | $ 5,929 | 10% |
| **TOTAL** | **$ 3,688,501** | **$ 923,996** | **25%** |

# Engineering & Technology Readiness

- Stave modification and system integration - done
  - **MVTX & INTT integration**
- Readout Electronics - done
  - **RU, PU, FELIX, Readout cable**
  - **Power system**
- Mechanical system – preliminary design available
  - **Detector design**
  - **Service & integration**
- Detector assembly and installation – plan developed
  - **Follow ALICE ITS procedures**

# Long Custom MVTX Readout Cables Tested



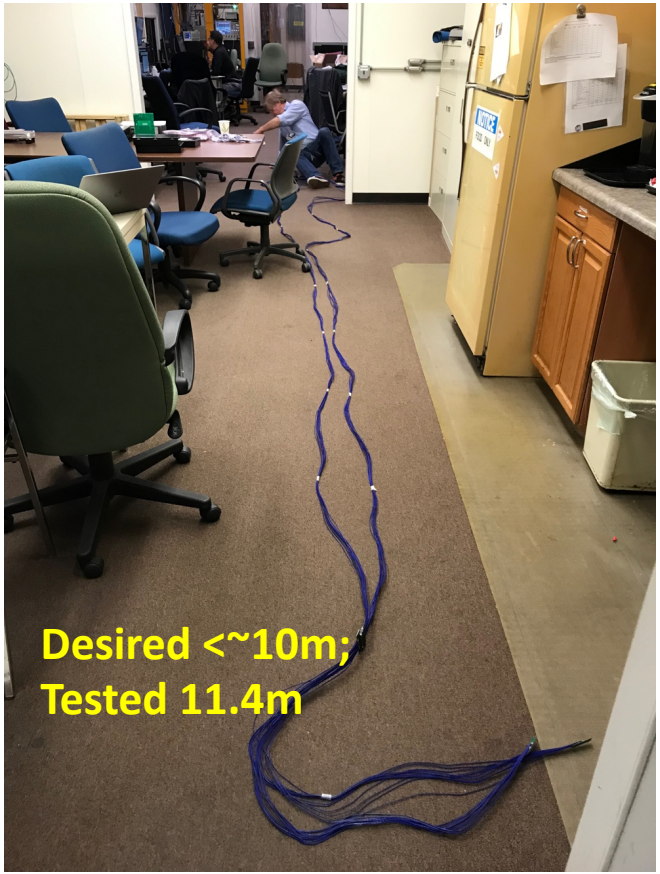

BNL has approved “non-halogen free” cables for sPHENIX

**sPHENIX MVTX: 7.9+m**

Cable-A: 1.4 m

Cable-B: 6.5+ m

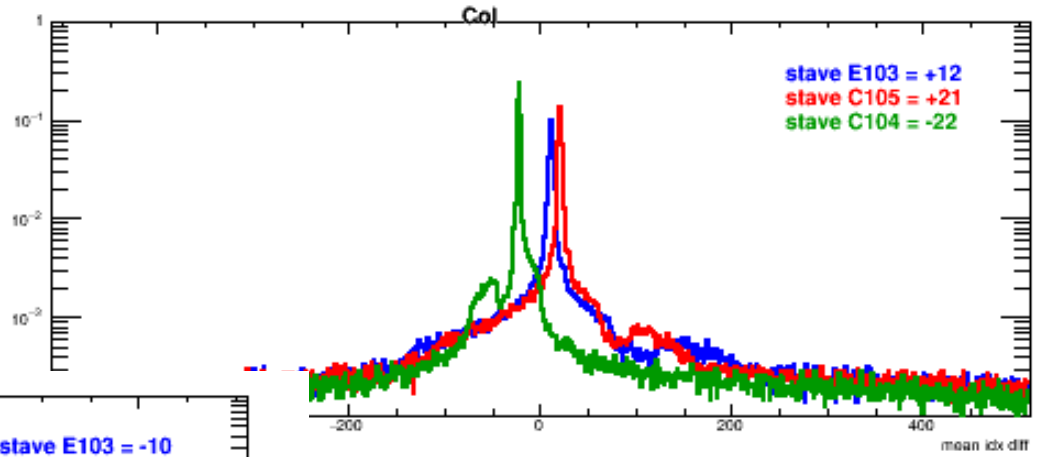
Power cable:4.7+ m

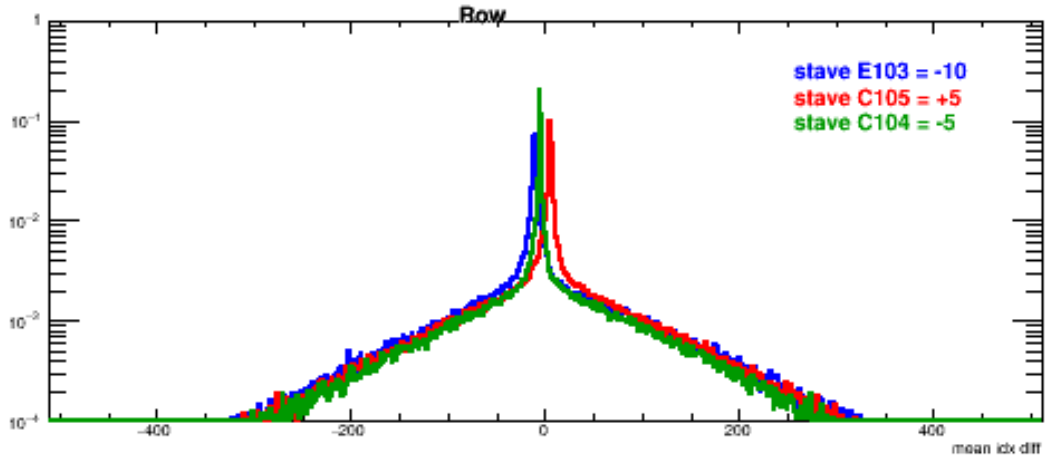


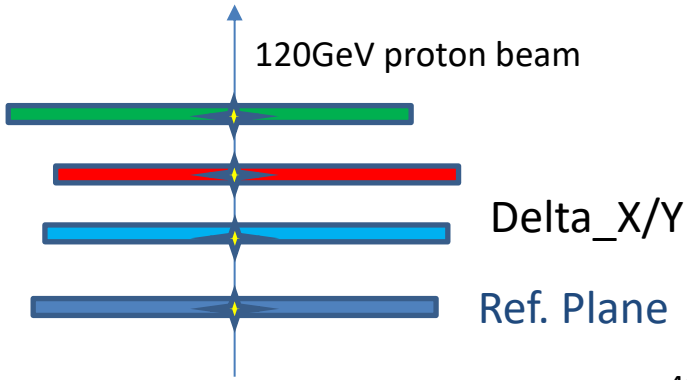
# Detector Misalignment & Hit Spatial Resolution Study

Typically staves offset by,
Horizontally: 20 x 30um = 600 um
Vertically: 5 x 30 um = 150 um

Hit spatial resolution: (w/o clustering)
Peak_sigma_core = 0.55 (pixel size ) =15 um
Chip spatial resolution = 15/sqrt(2) = 11 um
(same as 2018 TB results)

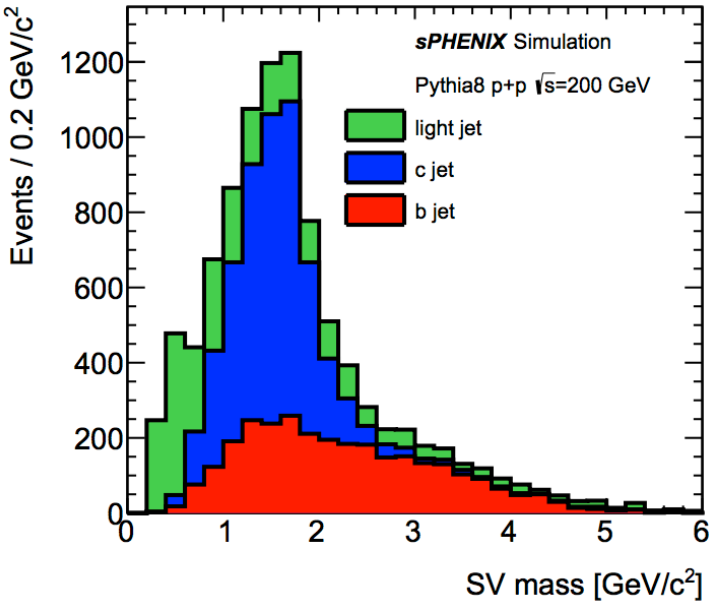


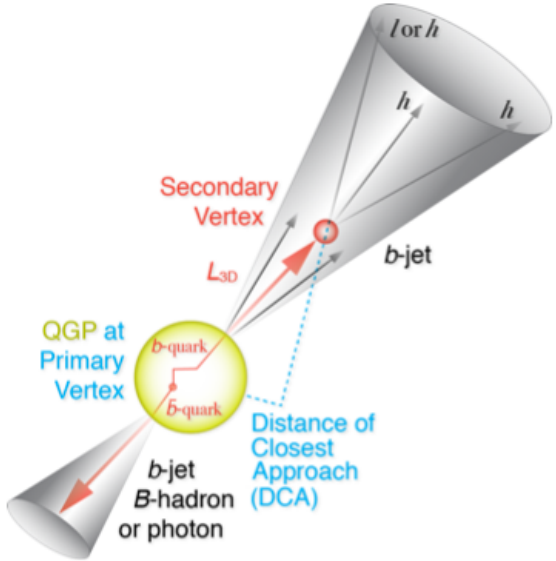



# B-Hadron & b-Jet Tagging

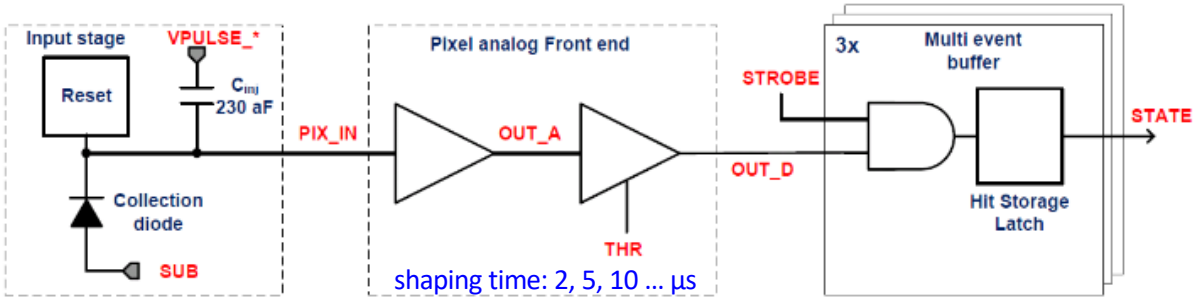
- Detected using the long lifetime of bottom quark hadrons:
  - Displaced tracks
  - Large 2nd vertex invariant mass
- Need high precision tracking and vertex determination – **MVTX!**
- Need excellent jet detection capabilities – **sPHENIX!**

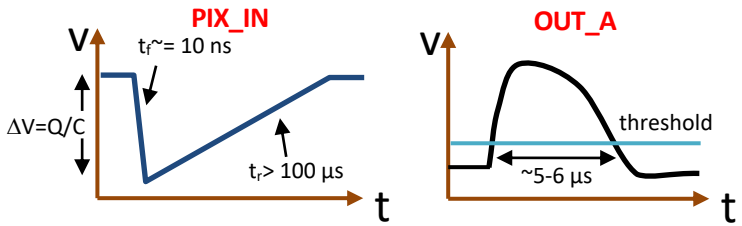


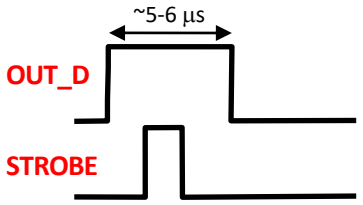



# ALPIDE/MAPS Operation

Well fit sPHENIX/RHIC environment, 10MHz Clock (LHC 40MHz)



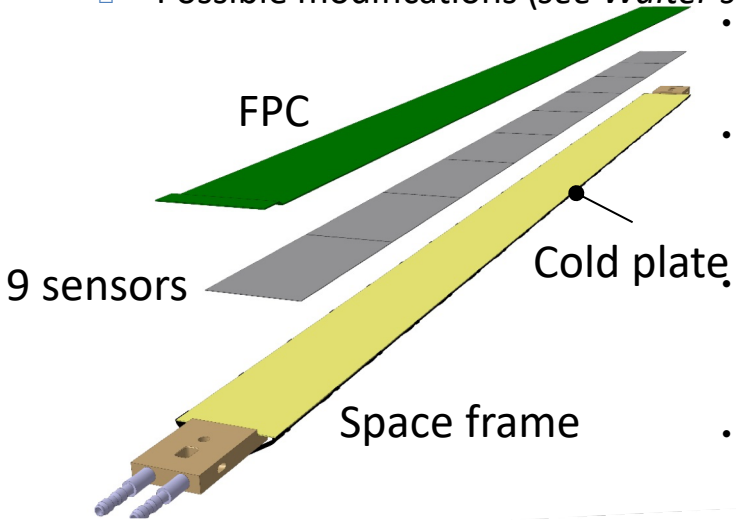




sPHENIX trigger latency: ~4 µs

# Staves - General layout

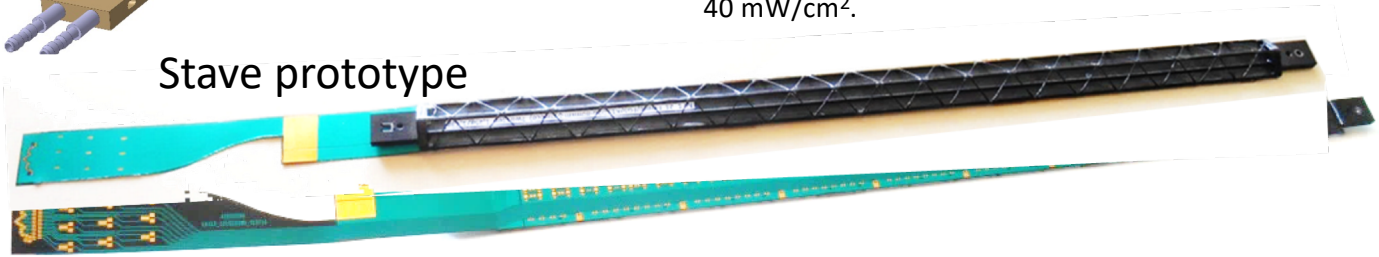
- Stave design developed by ALICE at no cost for MVTX project
- Possible modifications (*see Walter's talk*)



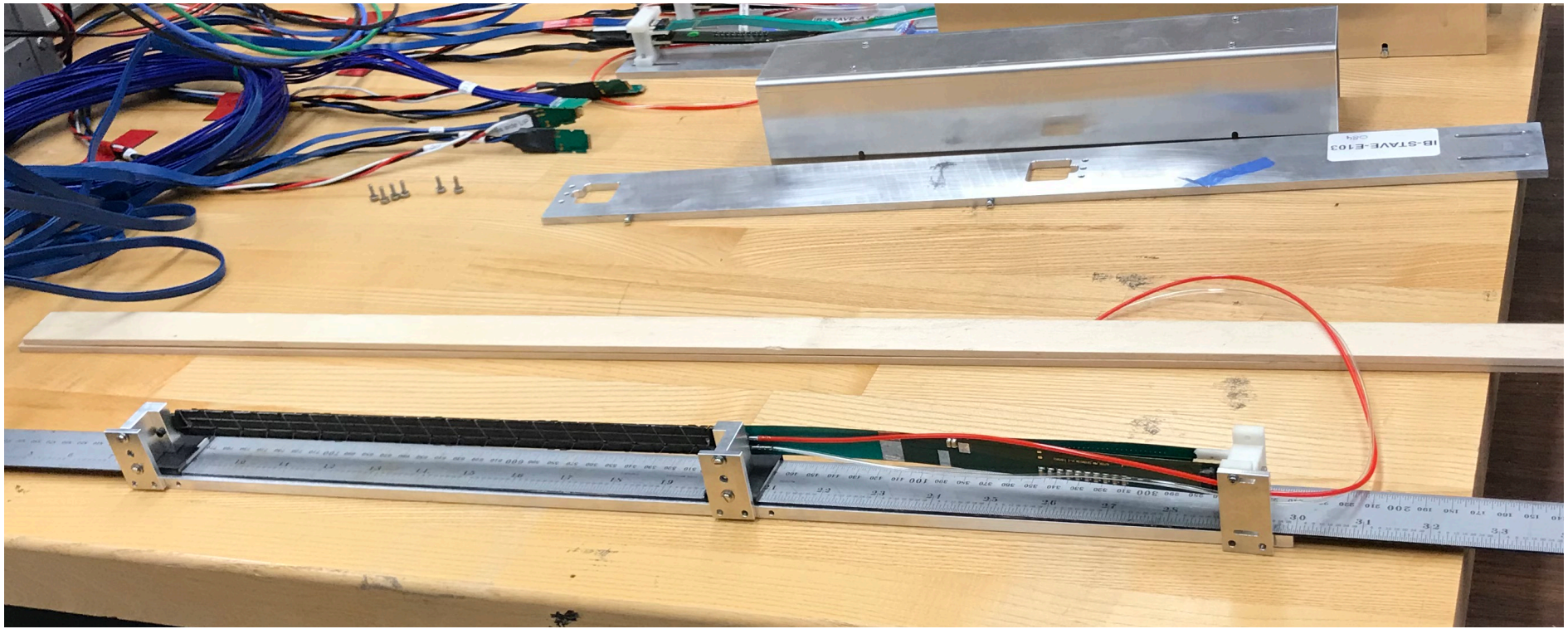

- **Staves:** detector modules consisting of a Hybrid Integrated Circuit (HIC) mounted on carbon fiber mechanical support structure
- **HIC:** a row of 9 ALPIDE sensors wire-bonded to a Flexible Printed Circuit (FPC). Area covered by the chips: 15x271.2 $mm^2$, including a gap of 150 µm between adjacent chips.

  **Mechanical support:** single light structure composed of a Space Frame, providing the required stiffness, and a Cold Plate, high-thermal conductivity carbon fiber sheet with embedded polyamide cooling pipes.
- **Heat Dissipation** – The ALPIDE sensors dissipate only 40 $mW/cm^2$.

Stave prototype



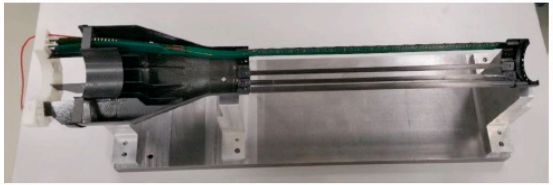
# ITS/IB Production Stave @LANL

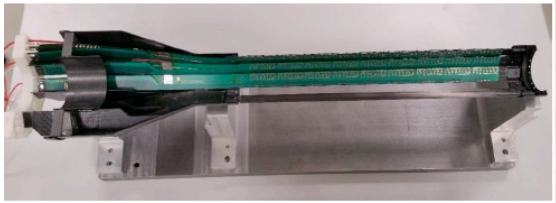


# ALICE ITS/IB Assembly

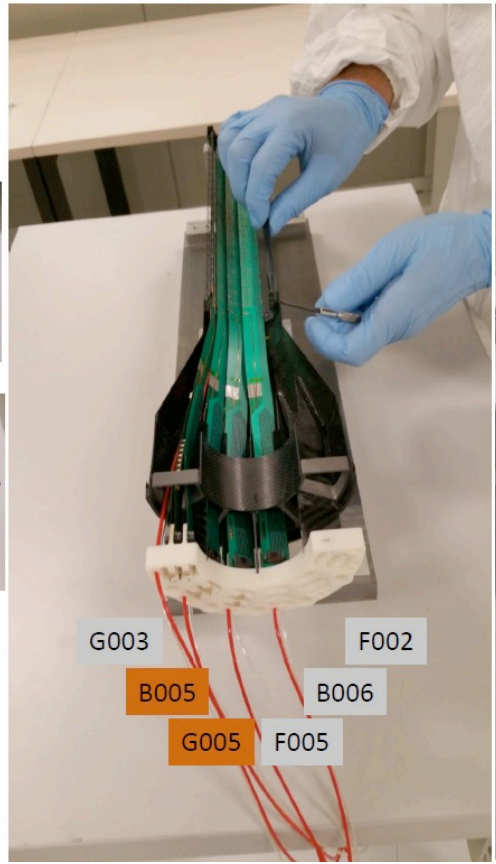
## IB-1 ½ Layer-0 assembly

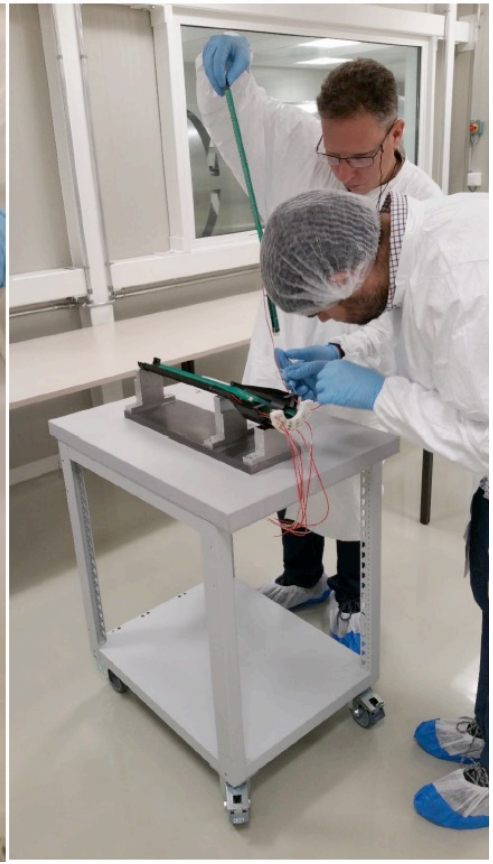
09/05/2018 @ 9:15



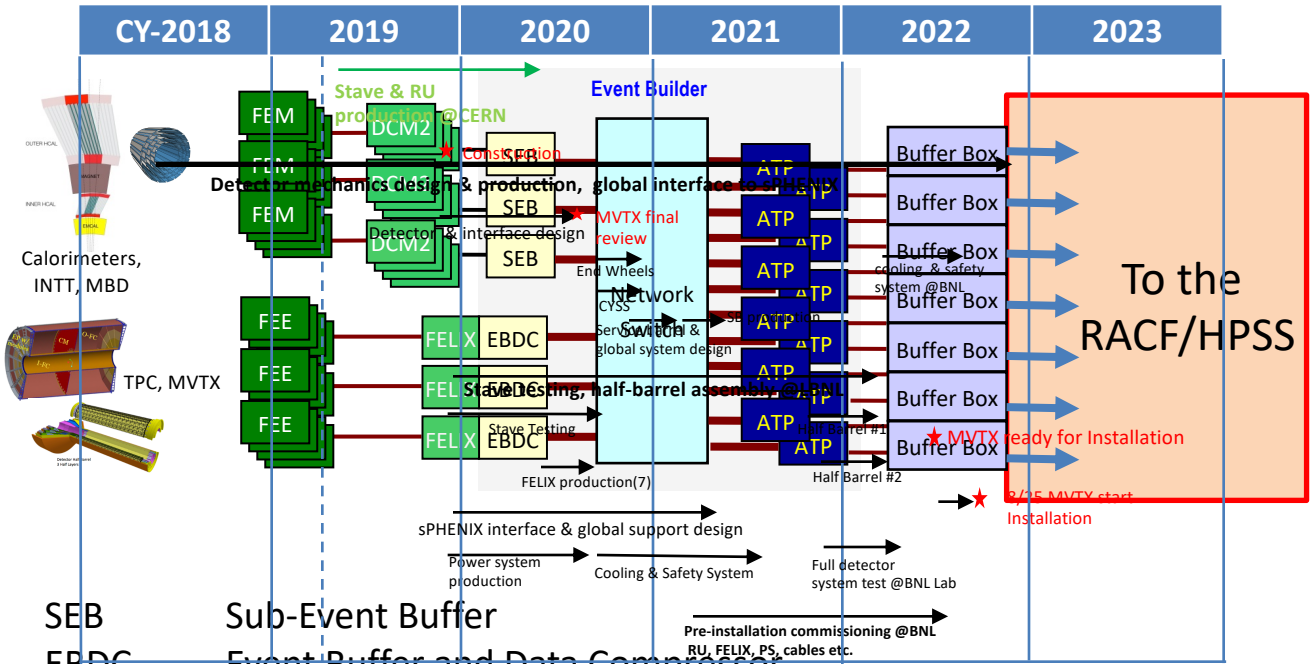


- Patch panel temporarily fixed with tape (waiting for validation of connector support)
- A lot of handling but no particular issues, mounting in 1.5 h
- **Power test OK**



# sPHENIX DAQ Architecture

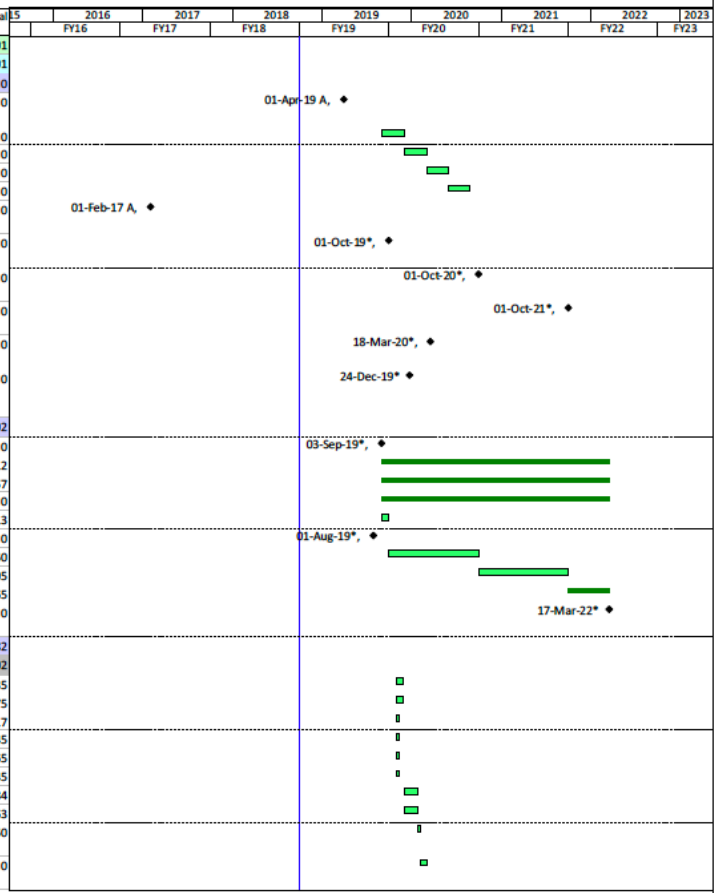



- SEB Sub-Event Buffer
- EBDC Event Buffer and Data Compressor
- ATP Assembles events and compresses data
- Buffer Box data interim storage before sending data to the computing center

# MVTX Project Detailed Schedule

Data Date: 01-Oct-18 Published: 25-Jul-19 16:48

| Activity ID | Activity Name | At Compl. Duration | Start | Finish | Total Float | Hours | Direct FY19$ - M&S | Burd AY$ - Labor | Burd AY$ - M&S | Burd AY$ - Total |
|---|---|---|---|---|---|---|---|---|---|---|
| POM02 sPHENIX WBS 3.02 Preliminary Baseline [MVTX] | | 1281.00 | 01-Feb-17 A | 17-Mar-22 | 0.00 | 21937 | 1189882 | 2,187,836 | 1,500,665 | 3,688,501 |
| MVTX | | 1281.00 | 01-Feb-17 A | 17-Mar-22 | 0.00 | 21937 | 1189882 | 2,187,836 | 1,500,665 | 3,688,501 |
| External Milestones in WBS 3x from WBS 1x, 2x | | 1169.00 | 01-Feb-17 A | 01-Oct-21 | 112.00 | 0 | 0 | 0 | 0 | 0 |
| S100000 | RU Production Start | 0.00 | 01-Apr-19 A | | | 0 | 0 | 0 | 0 | 0 |
| S100100 | Stave Production - Batch 1 | 62.00 | 03-Sep-19* | 03-Dec-19 | 101.00 | 0 | 0 | 0 | 0 | 0 |
| S100200 | Stave Production - Batch 2 | 62.00 | 04-Dec-19 | 04-Mar-20 | 101.00 | 0 | 0 | 0 | 0 | 0 |
| S100300 | Stave Production - Batch 3 | 62.00 | 05-Mar-20 | 01-Jun-20 | 101.00 | 0 | 0 | 0 | 0 | 0 |
| S100400 | Stave Production - Batch 4 | 62.00 | 02-Jun-20 | 27-Aug-20 | 101.00 | 0 | 0 | 0 | 0 | 0 |
| EXT100090 | [External Activity] Initial Project Funding Release | 0.00 | 01-Feb-17 A | | | 0 | 0 | 0 | 0 | 0 |
| EXT101010 | [External Activity] FY20 Funding Available | 0.00 | 01-Oct-19* | | 465.00 | 0 | 0 | 0 | 0 | 0 |
| EXT101015 | [External Activity] FY21 Funding Available | 0.00 | 01-Oct-20* | | 202.00 | 0 | 0 | 0 | 0 | 0 |
| EXT101016 | [External Activity] FY22 Funding Available | 0.00 | 01-Oct-21* | | 112.00 | 0 | 0 | 0 | 0 | 0 |
| EXT147100 | [External Activity] Procure TPC DAM Felix 2.0 Boards - Contract Award(s) | 0.00 | 18-Mar-20* | | 352.00 | 0 | 0 | 0 | 0 | 0 |
| EXT317000 | [External Activity] Design/Safety Reviews Complete, Internal Detector Structural Support Released for Production | 0.00 | | 24-Dec-19* | 287.00 | 0 | 0 | 0 | 0 | 0 |
| MVTX Project Management | | 655.00 | 01-Aug-19 | 17-Mar-22 | 0.00 | 1548 | 36250 | 497,769 | 46,833 | 544,602 |
| S100500 | Milestone Start MVTX | 0.00 | 03-Sep-19* | | 0.00 | 0 | 0 | 0 | 0 | 0 |
| S100600 | Project Manager | 633.00 | 03-Sep-19 | 17-Mar-22 | 0.00 | 1238 | 0 | 398,112 | 0 | 398,112 |
| S100700 | Mechanical Integration Engineer | 633.00 | 03-Sep-19 | 17-Mar-22 | 0.00 | 310 | 0 | 99,657 | 0 | 99,657 |
| S100800 | Electronics Integration Engineer | 633.00 | 03-Sep-19 | 17-Mar-22 | 0.00 | 0 | 0 | 0 | 0 | 0 |
| S100900 | Travel FY19 | 20.00 | 03-Sep-19 | 30-Sep-19 | 112.00 | 0 | 6250 | 0 | 7,813 | 7,813 |
| S101000 | MVTX Construction Start Approval | 0.00 | 01-Aug-19* | | 22.00 | 0 | 0 | 0 | 0 | 0 |
| S101100 | Travel FY20 | 251.00 | 01-Oct-19 | 30-Sep-20 | 112.00 | 0 | 10000 | 0 | 12,750 | 12,750 |
| S101200 | Travel FY21 | 250.00 | 01-Oct-20 | 30-Sep-21 | 112.00 | 0 | 10000 | 0 | 13,005 | 13,005 |
| S101300 | Travel FY22 | 112.00 | 01-Oct-21 | 17-Mar-22 | 0.00 | 0 | 10000 | 0 | 13,265 | 13,265 |
| S101400 | [EXTERNAL] MVTX Assembly Complete and Ready for Installation | 0.00 | | 17-Mar-22* | 0.00 | 0 | 0 | 0 | 0 | 0 |
| MVTX Electronics | | 260.00 | 03-Sep-19 | 15-Sep-20 | 293.00 | 2407 | 301084 | 211,165 | 358,417 | 569,582 |
| Readout Unit (RU) | | 220.00 | 30-Oct-19 | 15-Sep-20 | 293.00 | 1465 | 68545 | 129,007 | 83,995 | 213,002 |
| S101500 | Produce RU Cold Plate - Labor | 20.00 | 30-Oct-19 | 27-Nov-19 | 145.00 | 60 | 0 | 6,335 | 0 | 6,335 |
| S101700 | Produce RU Cold Plate - M&S | 20.00 | 30-Oct-19 | 27-Nov-19 | 145.00 | 0 | 15353 | 0 | 19,575 | 19,575 |
| S101600 | Procure Transition Board for RU M&S | 10.00 | 30-Oct-19 | 13-Nov-19 | 303.00 | 0 | 7935 | 0 | 10,117 | 10,117 |
| S101601 | Procure Transition Board for RU Labor | 10.00 | 30-Oct-19 | 13-Nov-19 | 303.00 | 8 | 0 | 845 | 0 | 845 |
| S101800 | Procure Power Mezzanine for RU M&S | 10.00 | 30-Oct-19 | 13-Nov-19 | 303.00 | 0 | 4757 | 0 | 6,065 | 6,065 |
| S101801 | Procure Power Mezzanine for RU Labor | 10.00 | 30-Oct-19 | 13-Nov-19 | 303.00 | 8 | 0 | 845 | 0 | 845 |
| S101900 | Test/QA RU - Labor | 40.00 | 02-Dec-19 | 29-Jan-20 | 293.00 | 420 | 0 | 33,784 | 0 | 33,784 |
| S102000 | Test/QA RU - M&S | 40.00 | 02-Dec-19 | 29-Jan-20 | 293.00 | 0 | 7500 | 0 | 9,563 | 9,563 |
| S102100 | Procure 60 SamTec Cables -Provide Requirements to Procurement | 5.00 | 30-Jan-20 | 05-Feb-20 | 293.00 | 5 | 0 | 950 | 0 | 950 |
| S102200 | Procure 60 SamTec Cables -Prepare & Send Solicitation | 20.00 | 06-Feb-20 | 05-Mar-20 | 293.00 | 0 | 0 | 0 | 0 | 0 |



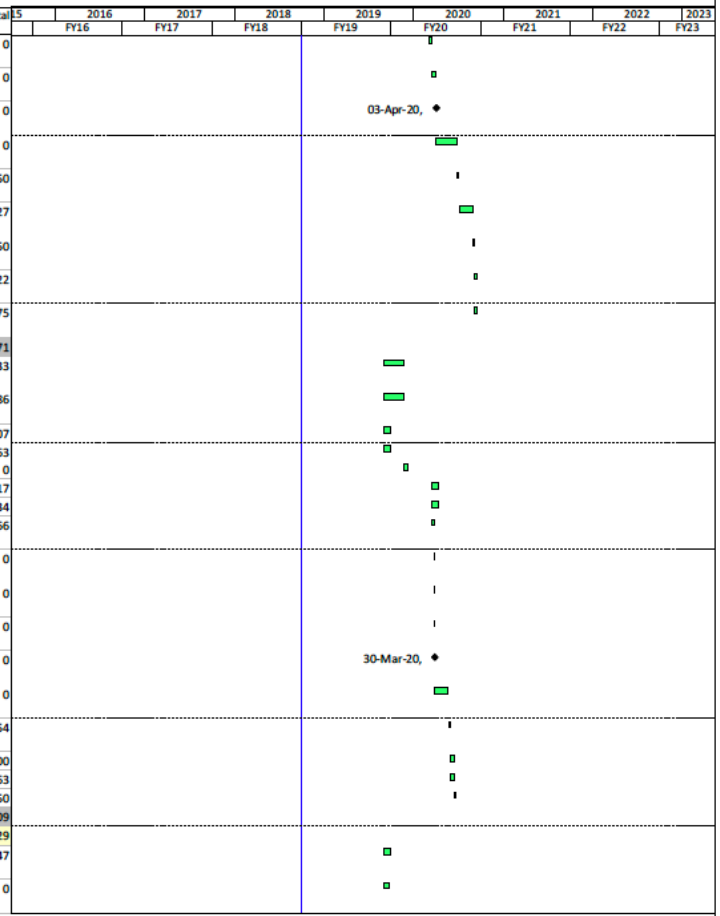



Actual Work | Critical Rem. Work | Remaining Work | Actual LoE | Remaining LoE | Milestone

# MVTX Project Detailed Schedule

Data Date: 01-Oct-18 Published: 25-Jul-19 16:48

| Activity ID | Activity Name | At Compl. Duration | Start | Finish | Total Float | Hours | Direct FY19$ - M&S | Burd AY$ - Labor | Burd AY$ - M&S | Burd AY$ - Total |
|---|---|---|---|---|---|---|---|---|---|---|
| S102300 | Procure 60 SamTec Cables -Vendor Responses | 10.00 | 06-Mar-20 | 19-Mar-20 | 293.00 | 0 | 0 | 0 | 0 | 0 |
| S102400 | Procure 60 SamTec Cables -Vendor Selection | 10.00 | 20-Mar-20 | 02-Apr-20 | 293.00 | 0 | 0 | 0 | 0 | 0 |
| S102500 | Procure 60 SamTec Cables -Contract Awards | 0.00 | 03-Apr-20 | | 293.00 | 0 | 0 | 0 | 0 | 0 |
| S102600 | Procure 60 SamTec Cables -Contract/PO - Leadtime | 60.00 | 03-Apr-20 | 26-Jun-20 | 293.00 | 0 | 0 | 0 | 0 | 0 |
| S102700 | Procure 60 SamTec Cables - Delivery Acceptance | 5.00 | 29-Jun-20 | 06-Jul-20 | 293.00 | 0 | 30000 | 0 | 34,850 | 34,850 |
| S102800 | Test/QA SamTec Cables Check if still needed | 40.00 | 07-Jul-20 | 31-Aug-20 | 293.00 | 960 | 0 | 85,827 | 0 | 85,827 |
| S102900 | Ship RU & SamTec Cables from CERN to UT Austin | 5.00 | 01-Sep-20 | 08-Sep-20 | 293.00 | 0 | 2000 | 0 | 2,550 | 2,550 |
| S102901 | Ship RU & SamTec Cables from UT Austin to BNL Labor | 5.00 | 09-Sep-20 | 15-Sep-20 | 293.00 | 4 | 0 | 422 | 0 | 422 |
| S102902 | Ship RU & SamTec Cables from UT Austin to BNL M&S | 5.00 | 09-Sep-20 | 15-Sep-20 | 293.00 | 0 | 1000 | 0 | 1,275 | 1,275 |
| FELIX 2.0 | | 201.00 | 03-Sep-19 | 22-Jun-20 | 352.00 | 195 | 76400 | 20,523 | 90,048 | 110,571 |
| S103000 | Produce Felix 2.0 first production unit - Labor | 57.00 | 03-Sep-19 | 22-Nov-19 | 148.00 | 16 | 0 | 3,133 | 0 | 3,133 |
| S103002 | Produce Felix 2.0 first production unit - M&S | 57.00 | 03-Sep-19 | 22-Nov-19 | 148.00 | 0 | 8000 | 0 | 9,186 | 9,186 |
| S103100 | Procure Optical Fiber - Labor | 20.00 | 03-Sep-19 | 30-Sep-19 | 455.00 | 2 | 0 | 307 | 0 | 307 |
| S103300 | Procure Optical Fiber - M&S | 20.00 | 03-Sep-19 | 30-Sep-19 | 455.00 | 0 | 50 | 0 | 63 | 63 |
| S103400 | Test/QA 1st Felix Unit and Fibers | 10.00 | 25-Nov-19 | 10-Dec-19 | 418.00 | 40 | 0 | 0 | 0 | 0 |
| S103450 | Procure 57 Optical Fiber Sets - Labor | 20.00 | 18-Mar-20 | 14-Apr-20 | 385.00 | 2 | 0 | 317 | 0 | 317 |
| S103460 | Procure 57 Optical Fiber Sets M&S | 20.00 | 18-Mar-20 | 14-Apr-20 | 385.00 | 0 | 2850 | 0 | 3,634 | 3,634 |
| S103500 | Procure 7 Felix 2.0 Remaining Units -Provide Requirements to Procurement | 5.00 | 18-Mar-20 | 24-Mar-20 | 352.00 | 6 | 0 | 1,266 | 0 | 1,266 |
| S103800 | Procure 7 Felix 2.0 Remaining Units -Prepare & Send Solicitation | 1.00 | 25-Mar-20 | 25-Mar-20 | 352.00 | 0 | 0 | 0 | 0 | 0 |
| S103900 | Procure 7 Felix 2.0 Remaining Units -Vendor Responses | 1.00 | 26-Mar-20 | 26-Mar-20 | 352.00 | 0 | 0 | 0 | 0 | 0 |
| S104000 | Procure 7 Felix 2.0 Remaining Units -Vendor Selection | 1.00 | 27-Mar-20 | 27-Mar-20 | 352.00 | 0 | 0 | 0 | 0 | 0 |
| S104100 | Procure 7 Felix 2.0 Remaining Units -Contract Awards | 0.00 | 30-Mar-20 | | 352.00 | 0 | 0 | 0 | 0 | 0 |
| S104200 | Procure 7 Felix 2.0 Remaining Units -Contract/PO - Leadtime | 40.00 | 30-Mar-20 | 22-May-20 | 352.00 | 0 | 0 | 0 | 0 | 0 |
| S104300 | Procure 7 Felix 2.0 Remaining Units - Delivery Acceptance | 5.00 | 26-May-20 | 01-Jun-20 | 352.00 | 0 | 56000 | 0 | 65,054 | 65,054 |
| S104400 | Test/QA 7 Felix Units and Fibers - Labor | 10.00 | 02-Jun-20 | 15-Jun-20 | 352.00 | 129 | 0 | 15,500 | 0 | 15,500 |
| S104500 | Test/QA 7 Felix Units and Fibers - M&S | 10.00 | 02-Jun-20 | 15-Jun-20 | 352.00 | 0 | 7500 | 0 | 9,563 | 9,563 |
| S104600 | Ship Felix Units and Fibers to BNL | 5.00 | 16-Jun-20 | 22-Jun-20 | 352.00 | 0 | 2000 | 0 | 2,550 | 2,550 |
| MAPS Power System | | 160.00 | 03-Sep-19 | 23-Apr-20 | 393.00 | 748 | 156139 | 61,635 | 184,374 | 246,009 |
| Power Boards | | 155.00 | 03-Sep-19 | 16-Apr-20 | 398.00 | 432 | 79020 | 50,629 | 93,700 | 144,329 |
| S105000 | Procure Power Distribution (harness) - Labor | 20.00 | 03-Sep-19 | 30-Sep-19 | 271.00 | 120 | 0 | 14,147 | 0 | 14,147 |
| S105100 | Procure Power Distribution (harness) - M&S | 19.00 | 03-Sep-19 | 27-Sep-19 | 494.00 | 0 | 0 | 0 | 0 | 0 |



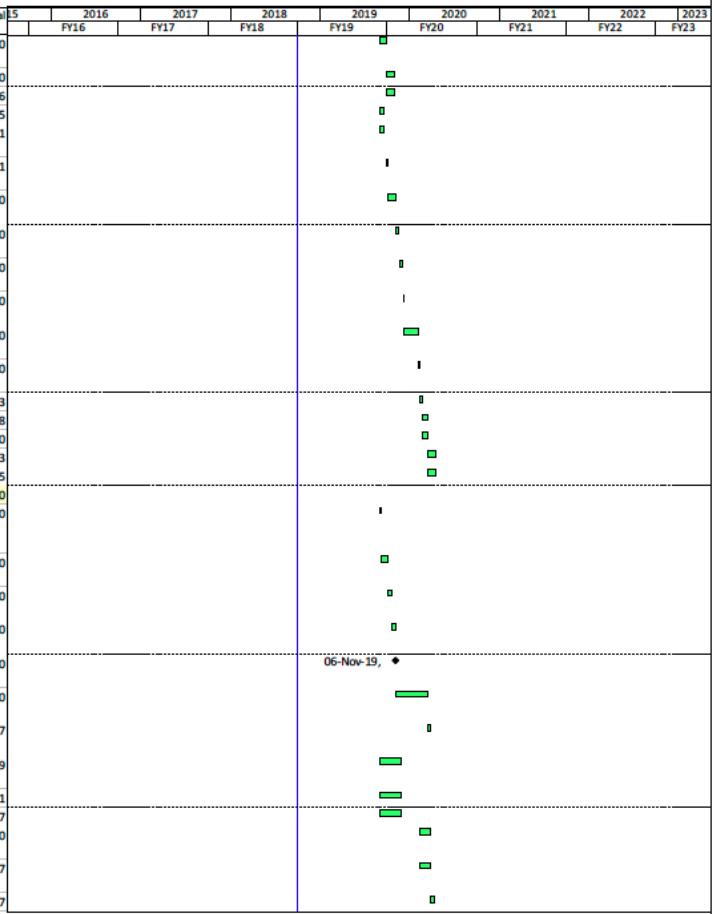



Actual Work | Critical Rem. Work | Remaining Work | Actual LoE | Remaining LoE | Milestone

# MVTX Project Detailed Schedule

Data Date: 01-Oct-18 Published: 25-Jul-19 16:48

| Activity ID | Activity Name | At Compl. Duration | Start | Finish | Total Float | Hours | Direct FY19$ - M&S | Burd AY$ - Labor | Burd AY$ - M&S | Burd AY$ - Total |
|---|---|---|---|---|---|---|---|---|---|---|
| S105700 | Fabricate Break Out Boards (qty?) - M&S | 20.00 | 03-Sep-19 | 30-Sep-19 | 176.00 | 0 | 6600 | 0 | 8,250 | 8,250 |
| S105800 | Fabricate PB to Stave Cables - M&S | 20.00 | 01-Oct-19 | 29-Oct-19 | 493.00 | 0 | 8000 | 0 | 10,200 | 10,200 |
| S105801 | Fabricate PB to Stave Cables - Labor | 20.00 | 01-Oct-19 | 29-Oct-19 | 493.00 | 60 | 0 | 7,286 | 0 | 7,286 |
| S106000 | Fabricate Cold (Cooling) Plates - M&S | 10.00 | 03-Sep-19 | 16-Sep-19 | 523.00 | 0 | 3420 | 0 | 4,275 | 4,275 |
| S106100 | Fabricate Cold (Cooling) Plates - Labor | 10.00 | 03-Sep-19 | 16-Sep-19 | 523.00 | 16 | 0 | 2,111 | 0 | 2,111 |
| S106160 | Procure Production PB -Provide Requirements to Procurement | 5.00 | 01-Oct-19 | 07-Oct-19 | 176.00 | 86 | 0 | 8,871 | 0 | 8,871 |
| S106200 | Procure Production PB -Prepare & Send Solicitation | 20.00 | 08-Oct-19 | 05-Nov-19 | 176.00 | 0 | 0 | 0 | 0 | 0 |
| S106300 | Procure Production PB -Vendor Responses | 10.00 | 06-Nov-19 | 20-Nov-19 | 176.00 | 0 | 0 | 0 | 0 | 0 |
| S106400 | Procure Production PB -Vendor Selection | 10.00 | 21-Nov-19 | 06-Dec-19 | 176.00 | 0 | 0 | 0 | 0 | 0 |
| S106500 | Procure Production PB -Contract Award | 0.00 | 09-Dec-19 | 09-Dec-19 | 176.00 | 0 | 0 | 0 | 0 | 0 |
| S106600 | Procure Production PB -Contract/PO - Leadtime | 40.00 | 09-Dec-19 | 05-Feb-20 | 176.00 | 0 | 0 | 0 | 0 | 0 |
| S106700 | Procure Production PB - Delivery Acceptance | 5.00 | 06-Feb-20 | 12-Feb-20 | 176.00 | 0 | 60000 | 0 | 69,700 | 69,700 |
| S106710 | Assemble PB Labor | 5.00 | 13-Feb-20 | 20-Feb-20 | 176.00 | 30 | 0 | 3,643 | 0 | 3,643 |
| S106730 | Test PB - Labor | 20.00 | 21-Feb-20 | 19-Mar-20 | 176.00 | 90 | 0 | 10,928 | 0 | 10,928 |
| S106770 | Test PB - M&S | 20.00 | 21-Feb-20 | 19-Mar-20 | 398.00 | 0 | 0 | 0 | 0 | 0 |
| S106780 | Ship PB to BNL Labor | 20.00 | 20-Mar-20 | 16-Apr-20 | 398.00 | 30 | 0 | 3,643 | 0 | 3,643 |
| S106785 | Ship PB to BNL M&S | 20.00 | 20-Mar-20 | 16-Apr-20 | 398.00 | 0 | 1000 | 0 | 1,275 | 1,275 |
| Power Supplies | | 160.00 | 03-Sep-19 | 23-Apr-20 | 393.00 | 315 | 77119 | 11,006 | 90,674 | 101,680 |
| S107050 | Procure CAEN A2518 Power Module (16) - Provide Requirements to Procurement | 5.00 | 03-Sep-19 | 09-Sep-19 | 393.00 | 209 | 0 | 0 | 0 | 0 |
| S107100 | Procure CAEN A2518Power Module (16) -Prepare & Send Solicitation | 20.00 | 10-Sep-19 | 07-Oct-19 | 393.00 | 0 | 0 | 0 | 0 | 0 |
| S107200 | Procure CAEN A2518Power Module (16) -Vendor Responses | 10.00 | 08-Oct-19 | 22-Oct-19 | 393.00 | 0 | 0 | 0 | 0 | 0 |
| S107300 | Procure CAEN A2518Power Module (16) -Vendor Selection | 10.00 | 23-Oct-19 | 05-Nov-19 | 393.00 | 0 | 0 | 0 | 0 | 0 |
| S107400 | Procure CAEN A2518Power Module (16) -Contract Award | 0.00 | 06-Nov-19 | | 393.00 | 0 | 0 | 0 | 0 | 0 |
| S107500 | Procure CAEN A2518Power Module (16) -Contract/PO - Leadtime | 90.00 | 06-Nov-19 | 19-Mar-20 | 393.00 | 0 | 0 | 0 | 0 | 0 |
| S107600 | Procure CAEN A2518Power Module (16) - Delivery Acceptance | 5.00 | 20-Mar-20 | 26-Mar-20 | 393.00 | 0 | 43676 | 0 | 50,737 | 50,737 |
| S107610 | Procure CAEN A3484 48V Power Supply | 60.00 | 03-Sep-19 | 27-Nov-19 | 473.00 | 0 | 8607 | 0 | 9,889 | 9,889 |
| S107620 | Procure CAEN SY4527 Main Frame | 60.00 | 03-Sep-19 | 27-Nov-19 | 473.00 | 0 | 11620 | 0 | 13,351 | 13,351 |
| S107640 | Procure CAEN A4532 Power Booster | 60.00 | 03-Sep-19 | 27-Nov-19 | 473.00 | 0 | 1216 | 0 | 1,397 | 1,397 |
| S107650 | Procure and terminate PS-to-PB (cabling) - M&S | 30.00 | 13-Feb-20 | 26-Mar-20 | 393.00 | 0 | 10000 | 0 | 12,750 | 12,750 |
| S107670 | Procure and terminate PS-to-PB (cabling) - Labor | 30.00 | 13-Feb-20 | 26-Mar-20 | 393.00 | 40 | 0 | 4,857 | 0 | 4,857 |
| S107700 | test PB with power supplies | 10.00 | 27-Mar-20 | 09-Apr-20 | 393.00 | 40 | 0 | 4,857 | 0 | 4,857 |



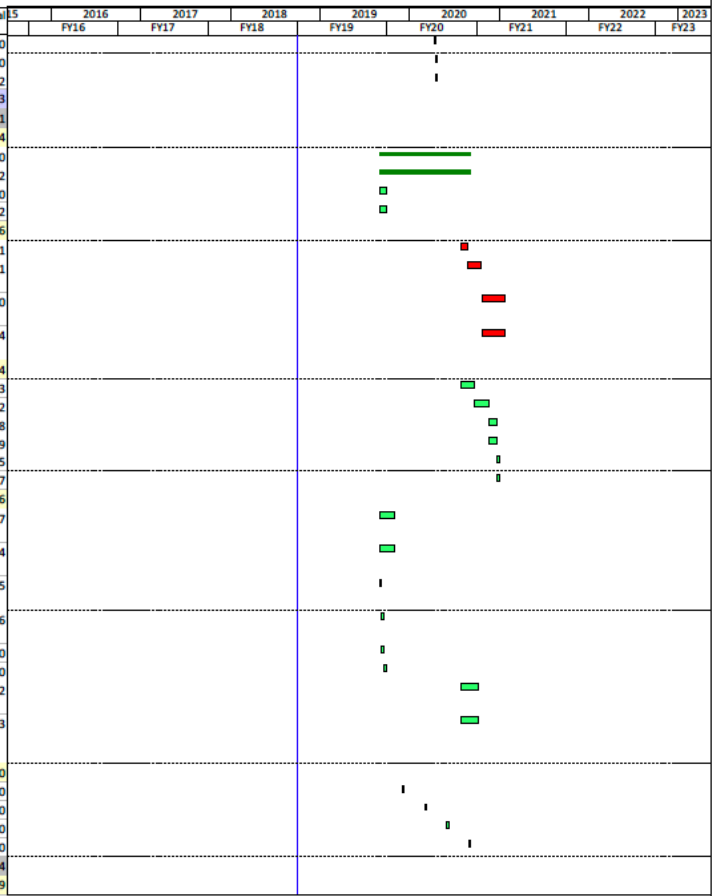



Actual Work | Critical Rem. Work | Remaining Work | Actual LoE | Remaining LoE | Milestone

# MVTX Project Detailed Schedule

Data Date: 01-Oct-18 Published: 25-Jul-19 16:48

| Activity ID | Activity Name | At Compl. Duration | Start | Finish | Total Float | Hours | Direct FY19$ - M&S | Burd AY$ - Labor | Burd AY$ - M&S | Burd AY$ - Total |
|---|---|---|---|---|---|---|---|---|---|---|
| S107800 | Document Power System | 5.00 | 10-Apr-20 | 16-Apr-20 | 393.00 | 16 | 0 | 0 | 0 | 0 |
| S107900 | Ship Power System to BNL - M&S | 5.00 | 17-Apr-20 | 23-Apr-20 | 393.00 | 0 | 2000 | 0 | 2,550 | 2,550 |
| S107910 | Ship Power System to BNL - Labor | 5.00 | 17-Apr-20 | 23-Apr-20 | 393.00 | 11 | 0 | 1,292 | 0 | 1,292 |
| MVTX Mechanics and Detector Assembly | | 632.00 | 03-Sep-19 | 16-Mar-22 | 1.00 | 14067 | 523486 | 1,022,061 | 678,912 | 1,700,973 |
| Staves | | 346.00 | 03-Sep-19 | 22-Jan-21 | 202.00 | 2509 | 146852 | 128,695 | 212,076 | 340,771 |
| Production | | 255.00 | 03-Sep-19 | 08-Sep-20 | 101.00 | 1287 | 57360 | 72 | 72,852 | 72,924 |
| S108000 | Test/QA Staves at CERN | 255.00 | 03-Sep-19 | 08-Sep-20 | 101.00 | 1280 | 0 | 0 | 0 | 0 |
| S108200 | Travel and Per Diem at CERN - M&S | 255.00 | 03-Sep-19 | 08-Sep-20 | 101.00 | 0 | 50000 | 0 | 63,652 | 63,652 |
| S108100 | CERN Test System - M&S | 20.00 | 03-Sep-19 | 30-Sep-19 | 291.00 | 0 | 7360 | 0 | 9,200 | 9,200 |
| S108300 | CERN Test System - Labor | 20.00 | 03-Sep-19 | 30-Sep-19 | 291.00 | 7 | 0 | 72 | 0 | 72 |
| Stave Assembly Tooling | | 120.00 | 29-Jul-20 | 22-Jan-21 | 0.00 | 264 | 25000 | 45,646 | 51,840 | 97,486 |
| S108400 | Stave Assembly Tooling - Design | 20.00 | 29-Jul-20 | 25-Aug-20 | 0.00 | 80 | 0 | 13,701 | 0 | 13,701 |
| S108700 | Stave Assembly Tooling - Final Jig Design | 40.00 | 26-Aug-20 | 22-Oct-20 | 0.00 | 160 | 0 | 27,711 | 0 | 27,711 |
| S108800 | Stave Assembly Tooling - Procure Assembly Fixtures and Tooling - M&S | 60.00 | 23-Oct-20 | 22-Jan-21 | 0.00 | 0 | 25000 | 0 | 51,840 | 51,840 |
| S108900 | Stave Assembly Tooling - Procure Assembly Fixtures and Tooling - Labor | 60.00 | 23-Oct-20 | 22-Jan-21 | 0.00 | 24 | 0 | 4,234 | 0 | 4,234 |
| Metrology | | 105.00 | 29-Jul-20 | 30-Dec-20 | 15.00 | 363 | 7000 | 61,319 | 14,515 | 75,834 |
| S109000 | Metrology design | 40.00 | 29-Jul-20 | 23-Sep-20 | 15.00 | 160 | 0 | 27,403 | 0 | 27,403 |
| S109100 | Design jigs | 40.00 | 24-Sep-20 | 20-Nov-20 | 15.00 | 160 | 0 | 28,122 | 0 | 28,122 |
| S109200 | Procure jigs - M&S | 20.00 | 23-Nov-20 | 22-Dec-20 | 15.00 | 0 | 5000 | 0 | 10,368 | 10,368 |
| S109300 | Procure jigs - Labor | 20.00 | 23-Nov-20 | 22-Dec-20 | 15.00 | 3 | 0 | 429 | 0 | 429 |
| S109400 | ship to LBNL - Labor | 5.00 | 23-Dec-20 | 30-Dec-20 | 15.00 | 40 | 0 | 5,365 | 0 | 5,365 |
| S109500 | ship to LBNL - M&S | 5.00 | 23-Dec-20 | 30-Dec-20 | 15.00 | 0 | 2000 | 0 | 4,147 | 4,147 |
| Shipping and Storage Containers | | 276.00 | 03-Sep-19 | 07-Oct-20 | 272.00 | 595 | 33492 | 21,657 | 42,269 | 63,926 |
| S109600 | Design & Fabricate Storage Cabinets for Staves - M&S | 40.00 | 03-Sep-19 | 29-Oct-19 | 264.00 | 0 | 6992 | 0 | 8,827 | 8,827 |
| S109610 | Design & Fabricate Storage Cabinets for Staves - Labor | 40.00 | 03-Sep-19 | 29-Oct-19 | 264.00 | 275 | 0 | 5,434 | 0 | 5,434 |
| S109700 | Design shipping container for 21 staves | 5.00 | 03-Sep-19 | 09-Sep-19 | 284.00 | 40 | 0 | 9,485 | 0 | 9,485 |
| S109900 | Procure Stave Shipping Plate (84) - Labor | 5.00 | 10-Sep-19 | 16-Sep-19 | 284.00 | 8 | 0 | 1,286 | 0 | 1,286 |
| S110000 | Procure Stave Shipping Plate (84) - M&S | 5.00 | 10-Sep-19 | 16-Sep-19 | 284.00 | 0 | 10000 | 0 | 12,500 | 12,500 |
| S110100 | Ship Stave Shipping Devices to CERN | 10.00 | 17-Sep-19 | 30-Sep-19 | 284.00 | 0 | 5000 | 0 | 6,250 | 6,250 |
| S110200 | Design & Fabricate Shipping and Storage Containers (Half-Barrels) - M&S | 50.00 | 29-Jul-20 | 07-Oct-20 | 272.00 | 0 | 11500 | 0 | 14,692 | 14,692 |
| S110300 | Design & Fabricate Shipping and Storage Containers (Half-Barrels) - Labor | 50.00 | 29-Jul-20 | 07-Oct-20 | 272.00 | 272 | 0 | 5,453 | 0 | 5,453 |
| Shipping the Staves from CERN to LBNL | | 193.00 | 04-Dec-19 | 08-Sep-20 | 101.00 | 0 | 24000 | 0 | 30,600 | 30,600 |
| S110400 | ship from CERN to LBNL - Batch 1 | 7.00 | 04-Dec-19 | 12-Dec-19 | 242.00 | 0 | 6000 | 0 | 7,650 | 7,650 |
| S110500 | ship from CERN to LBNL - Batch 2 | 7.00 | 05-Mar-20 | 13-Mar-20 | 195.00 | 0 | 6000 | 0 | 7,650 | 7,650 |
| S110600 | ship from CERN to LBNL - Batch 3 | 7.00 | 02-Jun-20 | 10-Jun-20 | 148.00 | 0 | 6000 | 0 | 7,650 | 7,650 |
| S110700 | ship from CERN to LBNL - Batch 4 | 7.00 | 28-Aug-20 | 08-Sep-20 | 101.00 | 0 | 6000 | 0 | 7,650 | 7,650 |
| Carbon Structures | | 632.00 | 03-Sep-19 | 16-Mar-22 | 1.00 | 3475 | 347820 | 681,389 | 428,975 | 1,110,364 |
| Mechanics Detector Design | | 100.00 | 03-Sep-19 | 29-Jan-20 | 0.00 | 640 | 0 | 200,199 | 0 | 200,199 |



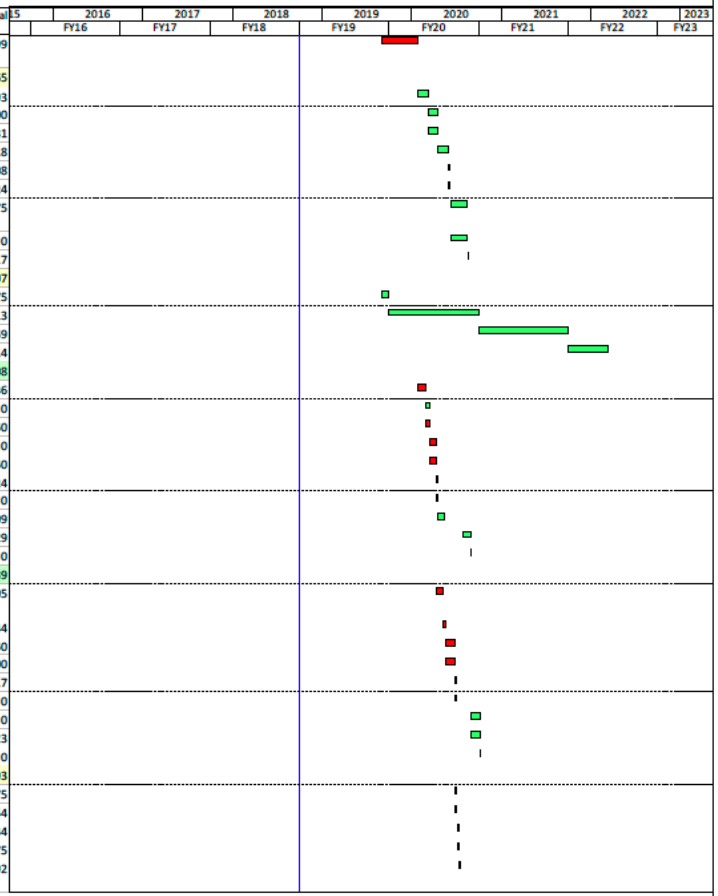



Actual Work | Critical Rem. Work | Remaining Work | Actual LoE | Remaining LoE | Milestone

# MVTX Project Detailed Schedule

Data Date: 01-Oct-18 Published: 25-Jul-19 16:48

| Activity ID | Activity Name | At Compl. Duration | Start | Finish | Total Float | Hours | Direct FY19$ - M&S | Burd AY$ - Labor | Burd AY$ - M&S | Burd AY$ - Total |
|---|---|---|---|---|---|---|---|---|---|---|
| S110800 | Develop MVTX inner tracker mechanical model LANL | 100.00 | 03-Sep-19 | 29-Jan-20 | 0.00 | 640 | 0 | 200,199 | 0 | 200,199 |
| End Wheels | | 142.00 | 30-Jan-20 | 19-Aug-20 | 104.00 | 1184 | 75940 | 220,841 | 90,024 | 310,865 |
| S110900 | End Weels Tooling Design | 30.00 | 30-Jan-20 | 12-Mar-20 | 20.00 | 140 | 0 | 34,193 | 0 | 34,193 |
| S111000 | End-wheels tooling material - M&S | 25.00 | 13-Mar-20 | 16-Apr-20 | 20.00 | 0 | 60000 | 0 | 69,700 | 69,700 |
| S111100 | End-wheels tooling material - Labor | 25.00 | 13-Mar-20 | 16-Apr-20 | 20.00 | 12 | 0 | 1,631 | 0 | 1,631 |
| S111200 | End wheels tooling assembly - Labor | 30.00 | 17-Apr-20 | 29-May-20 | 20.00 | 240 | 0 | 32,618 | 0 | 32,618 |
| S111400 | Procure end wheels material - Labor | 5.00 | 01-Jun-20 | 05-Jun-20 | 104.00 | 16 | 0 | 3,908 | 0 | 3,908 |
| S111500 | Procure end wheels material - M&S | 5.00 | 01-Jun-20 | 05-Jun-20 | 104.00 | 0 | 15940 | 0 | 20,324 | 20,324 |
| S111600 | End wheels production and test - Labor | 50.00 | 08-Jun-20 | 17-Aug-20 | 104.00 | 768 | 0 | 145,975 | 0 | 145,975 |
| S111700 | End wheels production and test - M&S | 50.00 | 08-Jun-20 | 17-Aug-20 | 104.00 | 0 | 0 | 0 | 0 | 0 |
| S111800 | Review End-wheels | 2.00 | 18-Aug-20 | 19-Aug-20 | 104.00 | 8 | 0 | 2,517 | 0 | 2,517 |
| Mechanics Fabrication | | 632.00 | 03-Sep-19 | 16-Mar-22 | 1.00 | 1491 | 261880 | 231,006 | 326,201 | 557,207 |
| S112600 | Travel LBNL - FY19 | 20.00 | 03-Sep-19 | 30-Sep-19 | 1.00 | 0 | 17500 | 0 | 21,875 | 21,875 |
| S112700 | Travel LBNL - FY20 | 251.00 | 01-Oct-19 | 30-Sep-20 | 1.00 | 0 | 17500 | 0 | 22,313 | 22,313 |
| S112800 | Travel LBNL - FY21 | 250.00 | 01-Oct-20 | 30-Sep-21 | 1.00 | 0 | 17500 | 0 | 22,759 | 22,759 |
| S112900 | Travel LBNL - FY22 | 111.00 | 01-Oct-21 | 16-Mar-22 | 1.00 | 0 | 17500 | 0 | 23,214 | 23,214 |
| Cylindrical Support Structure (CYSS) | | 151.00 | 30-Jan-20 | 02-Sep-20 | 382.00 | 754 | 75940 | 103,984 | 96,824 | 200,808 |
| S113000 | CYSS Tooling Design | 20.00 | 30-Jan-20 | 27-Feb-20 | 0.00 | 96 | 0 | 23,446 | 0 | 23,446 |
| S113100 | CYSS Tooling Material - Labor | 15.00 | 28-Feb-20 | 19-Mar-20 | 498.00 | 120 | 0 | 0 | 0 | 0 |
| S113200 | CYSS Tooling Material - M&S | 15.00 | 28-Feb-20 | 19-Mar-20 | 0.00 | 0 | 30000 | 0 | 38,250 | 38,250 |
| S113300 | CYSS Tooling Iteration - Labor | 15.00 | 20-Mar-20 | 09-Apr-20 | 0.00 | 24 | 0 | 0 | 0 | 0 |
| S113301 | CYSS Tooling Iteration - M&S | 15.00 | 20-Mar-20 | 09-Apr-20 | 0.00 | 0 | 30000 | 0 | 38,250 | 38,250 |
| S113400 | Procure CYSS Material - M&S | 5.00 | 10-Apr-20 | 16-Apr-20 | 278.00 | 0 | 15940 | 0 | 20,324 | 20,324 |
| S113500 | Procure CYSS Material - Labor | 5.00 | 10-Apr-20 | 16-Apr-20 | 298.00 | 8 | 0 | 0 | 0 | 0 |
| S113510 | CYSS Tooling assembly | 20.00 | 17-Apr-20 | 14-May-20 | 278.00 | 120 | 0 | 16,309 | 0 | 16,309 |
| S113700 | Production & Test CYSS - Labor | 25.00 | 29-Jul-20 | 01-Sep-20 | 227.00 | 386 | 0 | 64,229 | 0 | 64,229 |
| S113800 | Milestone: Complete CYSS | 0.00 | 02-Sep-20 | 02-Sep-20 | 227.00 | 0 | 0 | 0 | 0 | 0 |
| Service Barrel (SB) | | 126.00 | 10-Apr-20 | 08-Oct-20 | 272.00 | 737 | 115940 | 127,021 | 139,217 | 266,239 |
| S113900 | Review SB Design-Fabrication Compatibility | 20.00 | 10-Apr-20 | 07-May-20 | 0.00 | 91 | 0 | 12,505 | 0 | 12,505 |
| S114000 | Hold SB Review (PRR) | 10.00 | 08-May-20 | 21-May-20 | 0.00 | 112 | 0 | 12,644 | 0 | 12,644 |
| S114100 | SB Tooling - Labor | 25.00 | 22-May-20 | 26-Jun-20 | 0.00 | 240 | 0 | 49,950 | 0 | 49,950 |
| S114101 | SB Tooling - M&S | 25.00 | 22-May-20 | 26-Jun-20 | 0.00 | 0 | 40000 | 0 | 51,000 | 51,000 |
| S114200 | Procure SB Material - M&S | 5.00 | 29-Jun-20 | 06-Jul-20 | 313.00 | 0 | 75940 | 0 | 88,217 | 88,217 |
| S114300 | Procure SB Material - Labor | 5.00 | 29-Jun-20 | 06-Jul-20 | 313.00 | 8 | 0 | 0 | 0 | 0 |
| S114400 | Production & Test SB - M&S | 25.00 | 02-Sep-20 | 07-Oct-20 | 272.00 | 0 | 0 | 0 | 0 | 0 |
| S114500 | Production & Test SB - Labor | 25.00 | 02-Sep-20 | 07-Oct-20 | 272.00 | 286 | 0 | 51,923 | 0 | 51,923 |
| S114600 | Milestone: Complete SB | 0.00 | 08-Oct-20 | 08-Oct-20 | 272.00 | 0 | 0 | 0 | 0 | 0 |
| MVTX Final Design Review | | 21.00 | 29-Jun-20 | 28-Jul-20 | 0.00 | 160 | 10000 | 29,343 | 12,750 | 42,093 |
| S114700 | MVTX Design Review LBNL - M&S | 5.00 | 29-Jun-20 | 06-Jul-20 | 0.00 | 0 | 5000 | 0 | 6,375 | 6,375 |
| S114800 | MVTX Design Review LBNL - Labor | 5.00 | 29-Jun-20 | 06-Jul-20 | 0.00 | 40 | 0 | 1,954 | 0 | 1,954 |
| S114801 | MVTX Design Review LANL - Labor | 5.00 | 07-Jul-20 | 13-Jul-20 | 0.00 | 40 | 0 | 5,034 | 0 | 5,034 |
| S114810 | MVTX Design Review LANL - M&S | 5.00 | 07-Jul-20 | 13-Jul-20 | 0.00 | 0 | 5000 | 0 | 6,375 | 6,375 |
| S114900 | Incorporate MVTX Review Comments LBNL | 5.00 | 14-Jul-20 | 20-Jul-20 | 0.00 | 36 | 0 | 8,792 | 0 | 8,792 |



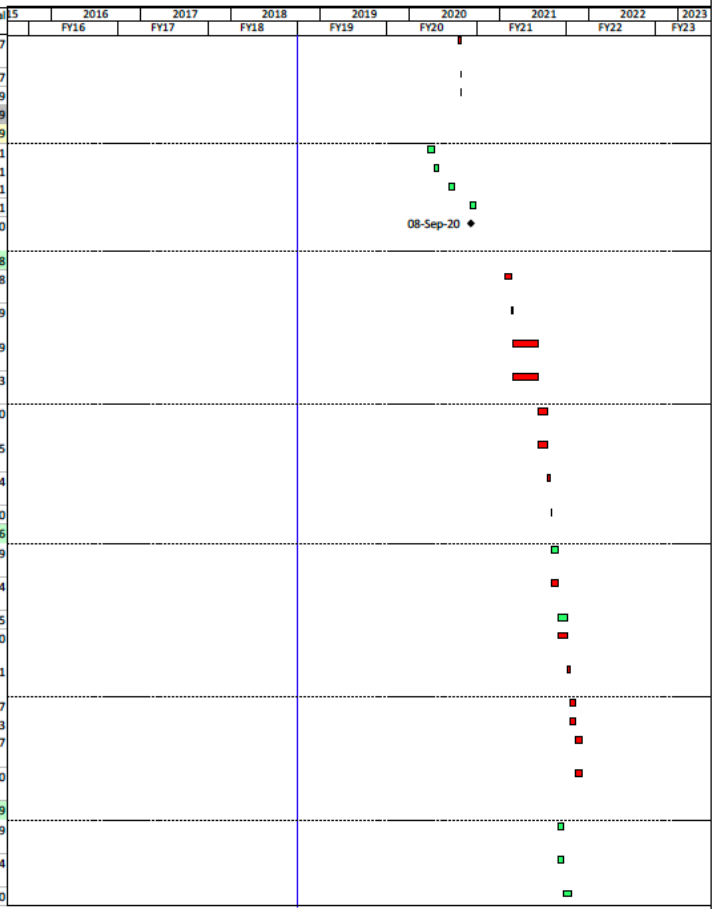



Actual Work | Critical Rem. Work | Remaining Work | Actual LoE | Remaining LoE | Milestone

# MVTX Project Detailed Schedule

Data Date: 01-Oct-18 Published: 25-Jul-19 16:48

| Activity ID | Activity Name | At Compl. Duration | Start | Finish | Total Float | Hours | Direct FY19$ - M&S | Burd AY$ - Labor | Burd AY$ - M&S | Burd AY$ - Total |
|---|---|---|---|---|---|---|---|---|---|---|
| S114910 | Incorporate MVTX Review Comments LANL | 5.00 | 21-Jul-20 | 27-Jul-20 | 0.00 | 36 | 0 | 11,327 | 0 | 11,327 |
| S115000 | Complete Final MVTX Design LBNL | 1.00 | 28-Jul-20 | 28-Jul-20 | 0.00 | 4 | 0 | 977 | 0 | 977 |
| S115010 | Complete Final MVTX Design LANL | 1.00 | 28-Jul-20 | 28-Jul-20 | 0.00 | 4 | 0 | 1,259 | 0 | 1,259 |
| Barrel Assembly | | 434.00 | 20-Mar-20 | 14-Dec-21 | 64.00 | 8084 | 28814 | 211,977 | 37,861 | 249,839 |
| Assembly and Testing | | 434.00 | 20-Mar-20 | 14-Dec-21 | 64.00 | 8084 | 28814 | 211,977 | 37,861 | 249,839 |
| S115100 | Test and Rework Staves - Batch 1 | 15.00 | 20-Mar-20 | 09-Apr-20 | 176.00 | 276 | 0 | 5,391 | 0 | 5,391 |
| S115200 | Test and Rework Staves - Batch 2 | 15.00 | 10-Apr-20 | 30-Apr-20 | 176.00 | 276 | 0 | 5,391 | 0 | 5,391 |
| S115300 | Test and Rework Staves - Batch 3 | 15.00 | 11-Jun-20 | 01-Jul-20 | 148.00 | 276 | 0 | 5,391 | 0 | 5,391 |
| S115500 | Test and Rework Staves - Batch 4 | 15.00 | 09-Sep-20 | 29-Sep-20 | 101.00 | 276 | 0 | 5,391 | 0 | 5,391 |
| S115400 | Milestone: Complete Reception of 84 Staves from CERN | 0.00 | | 08-Sep-20 | 101.00 | 0 | 0 | 0 | 0 | 0 |
| Layer Assembly and Test | | 132.00 | 25-Jan-21 | 02-Aug-21 | 0.00 | 2885 | 5336 | 70,039 | 6,939 | 76,978 |
| S115600 | Test Installation of Staves onto Layer End-Wheels | 20.00 | 25-Jan-21 | 22-Feb-21 | 0.00 | 368 | 0 | 7,208 | 0 | 7,208 |
| S115700 | Hold Half-Detector Assembly Review (PRR) | 5.00 | 23-Feb-21 | 01-Mar-21 | 0.00 | 96 | 0 | 2,729 | 0 | 2,729 |
| S115800 | Install Staves Onto Layer End-Wheels To Form Layers - M&S | 70.00 | 02-Mar-21 | 08-Jun-21 | 0.00 | 0 | 2760 | 0 | 3,589 | 3,589 |
| S115900 | Install Staves Onto Layer End-Wheels To Form Layers - Labor | 70.00 | 02-Mar-21 | 08-Jun-21 | 0.00 | 1484 | 0 | 34,303 | 0 | 34,303 |
| S116000 | Test and Rework Layers After Assembly - M&S | 25.00 | 09-Jun-21 | 14-Jul-21 | 0.00 | 0 | 2576 | 0 | 3,350 | 3,350 |
| S116100 | Test and Rework Layers After Assembly - Labor | 25.00 | 09-Jun-21 | 14-Jul-21 | 0.00 | 648 | 0 | 14,565 | 0 | 14,565 |
| S116200 | Perform Half-Detector Metrology On Layers | 12.00 | 15-Jul-21 | 30-Jul-21 | 0.00 | 289 | 0 | 11,234 | 0 | 11,234 |
| S116300 | Milestone: Complete Layers | 0.00 | 02-Aug-21 | 02-Aug-21 | 0.00 | 0 | 0 | 0 | 0 | 0 |
| Half Barrel #1 Assembly and Test | | 85.00 | 02-Aug-21 | 03-Dec-21 | 0.00 | 2046 | 11739 | 59,998 | 15,438 | 75,436 |
| S116400 | Assemble Layers and CYSS into Half Barrel #1 - M&S | 20.00 | 02-Aug-21 | 27-Aug-21 | 9.00 | 0 | 2760 | 0 | 3,589 | 3,589 |
| S116500 | Assemble Layers and CYSS into Half Barrel #1 - Labor | 20.00 | 02-Aug-21 | 27-Aug-21 | 0.00 | 408 | 0 | 13,894 | 0 | 13,894 |
| S116600 | Test and Rework Half Barrel #1 - M&S | 25.00 | 30-Aug-21 | 04-Oct-21 | 10.00 | 0 | 2576 | 0 | 3,355 | 3,355 |
| S116700 | Test and Rework Half Barrel #1 - Labor | 25.00 | 30-Aug-21 | 04-Oct-21 | 0.00 | 679 | 0 | 18,840 | 0 | 18,840 |
| S116800 | Perform Half Barrel #1 Metrology On Final Assembly - Labor | 10.00 | 05-Oct-21 | 19-Oct-21 | 0.00 | 216 | 0 | 8,181 | 0 | 8,181 |
| S116900 | Validation Of Final Assembly - M&S | 15.00 | 20-Oct-21 | 09-Nov-21 | 0.00 | 0 | 2576 | 0 | 3,417 | 3,417 |
| S117000 | Validation Of Final Assembly - Labor | 15.00 | 20-Oct-21 | 09-Nov-21 | 0.00 | 568 | 0 | 14,093 | 0 | 14,093 |
| S117100 | Pack/Ship Final Assemblies of Half Barrel #1 To BNL - M&S | 15.00 | 10-Nov-21 | 03-Dec-21 | 0.00 | 0 | 3827 | 0 | 5,077 | 5,077 |
| S117200 | Pack/Ship Final Assemblies of Half Barrel #1 To BNL - Labor | 15.00 | 10-Nov-21 | 03-Dec-21 | 0.00 | 175 | 0 | 4,990 | 0 | 4,990 |
| Half Barrel #2 Assembly and Test | | 71.00 | 30-Aug-21 | 14-Dec-21 | 64.00 | 2046 | 11739 | 60,375 | 15,483 | 75,859 |
| S117300 | Assemble Layers and CYSS Into Half Barrel #2 - M&S | 18.00 | 30-Aug-21 | 23-Sep-21 | 9.00 | 0 | 2760 | 0 | 3,589 | 3,589 |
| S117400 | Assemble Layers and CYSS Into Half Barrel #2 - Labor | 18.00 | 30-Aug-21 | 23-Sep-21 | 9.00 | 408 | 0 | 13,894 | 0 | 13,894 |
| S117500 | Test and Rework Half Barrel #2 - M&S | 20.00 | 24-Sep-21 | 22-Oct-21 | 9.00 | 0 | 2576 | 0 | 3,400 | 3,400 |



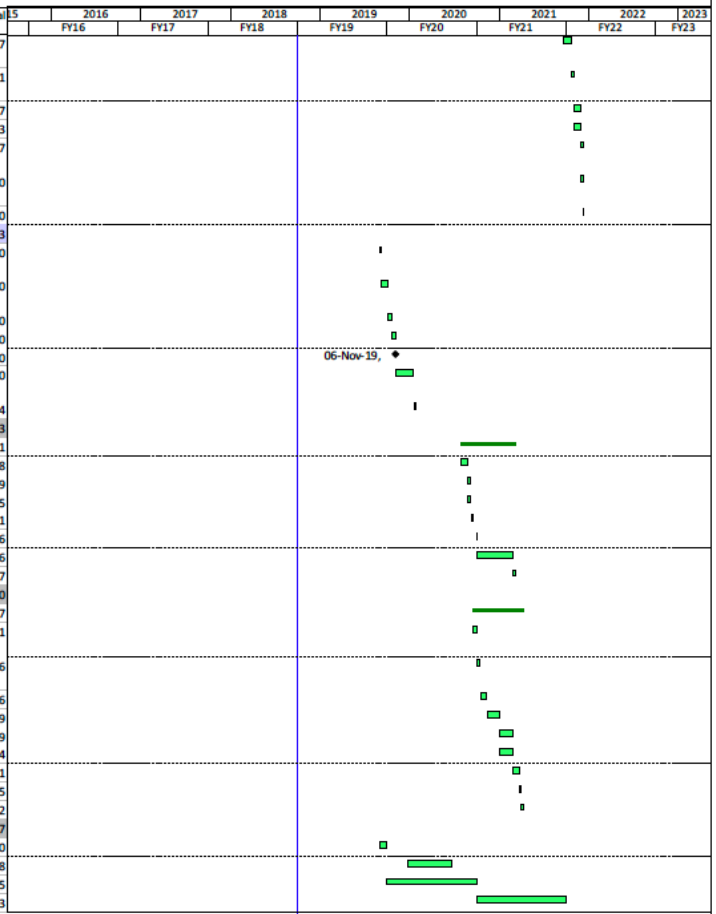



Actual Work | Critical Rem. Work | Remaining Work | Actual LoE | Remaining LoE | Milestone

# MVTX Project Detailed Schedule

Data Date: 01-Oct-18 Published: 25-Jul-19 16:48

| Activity ID | Activity Name | At Compl. Duration | Start | Finish | Total Float | Hours | Direct FY19$ - M&S | Burd AY$ - Labor | Burd AY$ - M&S | Burd AY$ - Total |
|---|---|---|---|---|---|---|---|---|---|---|
| S117600 | Test and Rework Half Barrel #2 - Labor | 20.00 | 24-Sep-21 | 22-Oct-21 | 9.00 | 679 | 0 | 19,217 | 0 | 19,217 |
| S117700 | Perform Half Barrel #2 Metrology On Final Assembly | 8.00 | 25-Oct-21 | 03-Nov-21 | 9.00 | 216 | 0 | 8,181 | 0 | 8,181 |
| S117800 | Validation Of Final Assembly - M&S | 15.00 | 04-Nov-21 | 29-Nov-21 | 9.00 | 0 | 2576 | 0 | 3,417 | 3,417 |
| S117900 | Validation Of Final Assembly - Labor | 15.00 | 04-Nov-21 | 29-Nov-21 | 9.00 | 568 | 0 | 14,093 | 0 | 14,093 |
| S118000 | Pack/Ship Final Assemblies of Half Barrel #2 to BNL - M&S | 10.00 | 30-Nov-21 | 13-Dec-21 | 9.00 | 0 | 3827 | 0 | 5,077 | 5,077 |
| S118100 | Pack/Ship Final Assemblies of Half Barrel #2 to BNL - Labor | 10.00 | 30-Nov-21 | 13-Dec-21 | 9.00 | 175 | 0 | 4,990 | 0 | 4,990 |
| S118200 | Milestone: Complete Barrel (RR) | 0.00 | 14-Dec-21 | 14-Dec-21 | 64.00 | 0 | 0 | 0 | 0 | 0 |
| MVTX Integration and Infrastructure | | 633.00 | 03-Sep-19 | 17-Mar-22 | 0.00 | 3914 | 329062 | 456,841 | 416,503 | 873,343 |
| S118300 | Clean Tent/Room -Provide Requirements to Procurement | 5.00 | 03-Sep-19 | 09-Sep-19 | 535.00 | 0 | 0 | 0 | 0 | 0 |
| S118400 | Clean Tent/Room -Prepare & Send Solicitation | 20.00 | 10-Sep-19 | 07-Oct-19 | 535.00 | 0 | 0 | 0 | 0 | 0 |
| S118500 | Clean Tent/Room -Vendor Responses | 10.00 | 08-Oct-19 | 22-Oct-19 | 535.00 | 0 | 0 | 0 | 0 | 0 |
| S118600 | Clean Tent/Room -Vendor Selection | 10.00 | 23-Oct-19 | 05-Nov-19 | 535.00 | 0 | 0 | 0 | 0 | 0 |
| S118700 | Clean Tent/Room -Contract Award | 0.00 | 06-Nov-19 | | 535.00 | 0 | 0 | 0 | 0 | 0 |
| S118800 | Clean Tent/Room -Contract/PO - Leadtime | 48.00 | 06-Nov-19 | 17-Jan-20 | 535.00 | 0 | 0 | 0 | 0 | 0 |
| S118900 | Clean Tent/Room - Delivery Acceptance | 5.00 | 21-Jan-20 | 27-Jan-20 | 535.00 | 0 | 50000 | 0 | 58,084 | 58,084 |
| Cooling System | | 150.00 | 29-Jul-20 | 08-Mar-21 | 202.00 | 332 | 87000 | 47,710 | 124,523 | 172,233 |
| S119000 | Cooling System - MIT Travel | 150.00 | 29-Jul-20 | 08-Mar-21 | 202.00 | 0 | 25000 | 0 | 32,321 | 32,321 |
| S119100 | Design Cooling (Modify ALICE Design) | 20.00 | 29-Jul-20 | 25-Aug-20 | 162.00 | 160 | 0 | 24,118 | 0 | 24,118 |
| S119200 | Mock up Testing - M&S | 10.00 | 26-Aug-20 | 09-Sep-20 | 162.00 | 0 | 20000 | 0 | 40,659 | 40,659 |
| S119300 | Mock up Testing - Labor | 10.00 | 26-Aug-20 | 09-Sep-20 | 162.00 | 100 | 0 | 14,595 | 0 | 14,595 |
| S119400 | Final Design of Cooling System | 5.00 | 10-Sep-20 | 16-Sep-20 | 162.00 | 40 | 0 | 6,851 | 0 | 6,851 |
| S119500 | Procure Cooling Plant - M&S | 0.00 | 01-Oct-20 | 01-Oct-20 | 302.00 | 0 | 40000 | 0 | 47,396 | 47,396 |
| S119600 | Procure Cooling Plant - Labor | 100.00 | 01-Oct-20 | 01-Mar-21 | 202.00 | 32 | 0 | 2,146 | 0 | 2,146 |
| S119700 | Ship Cooling Plant to BNL | 5.00 | 02-Mar-21 | 08-Mar-21 | 202.00 | 0 | 2000 | 0 | 4,147 | 4,147 |
| Safety Systems | | 140.00 | 17-Sep-20 | 12-Apr-21 | 162.00 | 986 | 35200 | 107,210 | 44,731 | 151,940 |
| S119800 | Safety Systems - MIT Travel | 140.00 | 17-Sep-20 | 12-Apr-21 | 162.00 | 0 | 25000 | 0 | 32,467 | 32,467 |
| S119900 | Define MVTX Safety and Interlock requirements | 10.00 | 17-Sep-20 | 30-Sep-20 | 162.00 | 120 | 0 | 6,851 | 0 | 6,851 |
| S120000 | Review Sensors & Interlocks with BNL ES&H | 10.00 | 01-Oct-20 | 15-Oct-20 | 162.00 | 80 | 0 | 7,056 | 0 | 7,056 |
| S120100 | Design Electronics Safety System | 20.00 | 16-Oct-20 | 13-Nov-20 | 162.00 | 288 | 0 | 14,516 | 0 | 14,516 |
| S120200 | Design Cooling Interlocks | 30.00 | 16-Nov-20 | 30-Dec-20 | 162.00 | 120 | 0 | 21,169 | 0 | 21,169 |
| S120300 | Procure Safety Systems - M&S | 40.00 | 31-Dec-20 | 01-Mar-21 | 162.00 | 0 | 10000 | 0 | 11,849 | 11,849 |
| S120400 | Procure Safety Systems - Labor | 40.00 | 31-Dec-20 | 01-Mar-21 | 162.00 | 58 | 0 | 9,484 | 0 | 9,484 |
| S120500 | Test Safety Systems at MIT | 15.00 | 02-Mar-21 | 22-Mar-21 | 162.00 | 161 | 0 | 23,291 | 0 | 23,291 |
| S120600 | Ship Safety Systems to BNL | 5.00 | 23-Mar-21 | 29-Mar-21 | 162.00 | 0 | 200 | 0 | 415 | 415 |
| S120700 | Test Safety Systems at BNL | 10.00 | 30-Mar-21 | 12-Apr-21 | 162.00 | 160 | 0 | 24,842 | 0 | 24,842 |
| Service Barrel Support Frame & MVTX Interface to sPHENIX | | 633.00 | 03-Sep-19 | 17-Mar-22 | 0.00 | 1420 | 156862 | 242,632 | 189,165 | 431,797 |
| S120800 | Travel FY19 | 20.00 | 03-Sep-19 | 30-Sep-19 | 112.00 | 0 | 2560 | 0 | 3,200 | 3,200 |
| S120900 | Design Interface to sPHENIX | 125.00 | 24-Dec-19 | 22-Jun-20 | 287.00 | 1000 | 0 | 171,268 | 0 | 171,268 |
| S121000 | Travel FY20 | 251.00 | 01-Oct-19 | 30-Sep-20 | 112.00 | 0 | 5000 | 0 | 6,375 | 6,375 |
| S122000 | Travel FY21 | 250.00 | 01-Oct-20 | 30-Sep-21 | 112.00 | 0 | 5000 | 0 | 6,503 | 6,503 |

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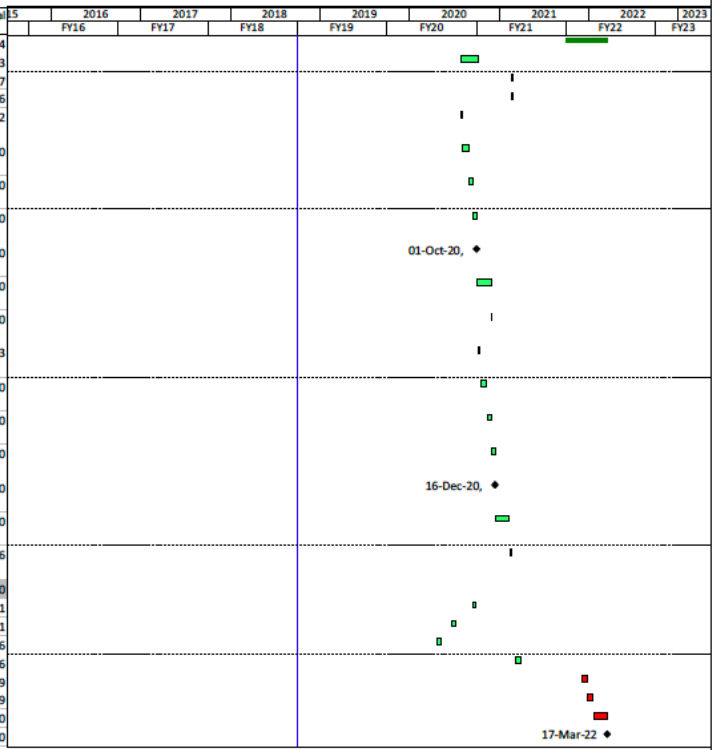
Actual Work | Critical Rem. Work | Remaining Work | Actual LoE | Remaining LoE | Milestone

# MVTX Project Detailed Schedule

Data Date: 01-Oct-18 Published: 25-Jul-19 16:48

| Activity ID | Activity Name | At Compl. Duration | Start | Finish | Total Float | Hours | Direct FY19$ - M&S | Burd AY$ - Labor | Burd AY$ - M&S | Burd AY$ - Total |
|---|---|---|---|---|---|---|---|---|---|---|
| S123000 | Travel FY22 | 112.00 | 01-Oct-21 | 17-Mar-22 | 0.00 | 0 | 2302 | 0 | 3,054 | 3,054 |
| S121800 | Design Insertion System | 50.00 | 29-Jul-20 | 07-Oct-20 | 262.00 | 400 | 0 | 68,713 | 0 | 68,713 |
| S122800 | ship to BNL - M&S | 5.00 | 23-Feb-21 | 01-Mar-21 | 262.00 | 0 | 2000 | 0 | 4,147 | 4,147 |
| S122900 | ship to BNL - Labor | 5.00 | 23-Feb-21 | 01-Mar-21 | 262.00 | 4 | 0 | 536 | 0 | 536 |
| S121100 | Procure Support Structure -Provide Requirements to Procurement | 5.00 | 29-Jul-20 | 04-Aug-20 | 316.00 | 8 | 0 | 1,042 | 0 | 1,042 |
| S121200 | Procure Support Structure -Prepare & Send Solicitation | 20.00 | 05-Aug-20 | 01-Sep-20 | 316.00 | 0 | 0 | 0 | 0 | 0 |
| S121300 | Procure Support Structure -Vendor Responses | 10.00 | 02-Sep-20 | 16-Sep-20 | 316.00 | 0 | 0 | 0 | 0 | 0 |
| S121400 | Procure Support Structure -Vendor Selection | 10.00 | 17-Sep-20 | 30-Sep-20 | 316.00 | 0 | 0 | 0 | 0 | 0 |
| S121500 | Procure Support Structure -Contract Award | 0.00 | 01-Oct-20 | | 316.00 | 0 | 0 | 0 | 0 | 0 |
| S121600 | Procure Support Structure -Contract/PO - Leadtime | 40.00 | 01-Oct-20 | 01-Dec-20 | 316.00 | 0 | 0 | 0 | 0 | 0 |
| S121700 | Procure Support Structure - Delivery Acceptance | 1.00 | 02-Dec-20 | 02-Dec-20 | 316.00 | 0 | 100000 | 0 | 118,490 | 118,490 |
| S122100 | Procure Insertion System -Provide Requirements to Procurement | 5.00 | 08-Oct-20 | 15-Oct-20 | 262.00 | 8 | 0 | 1,073 | 0 | 1,073 |
| S122200 | Procure Insertion System -Prepare & Send Solicitation | 20.00 | 16-Oct-20 | 13-Nov-20 | 262.00 | 0 | 0 | 0 | 0 | 0 |
| S122300 | Procure Insertion System -Vendor Responses | 10.00 | 16-Nov-20 | 01-Dec-20 | 262.00 | 0 | 0 | 0 | 0 | 0 |
| S122400 | Procure Insertion System -Vendor Selection | 10.00 | 02-Dec-20 | 15-Dec-20 | 262.00 | 0 | 0 | 0 | 0 | 0 |
| S122500 | Procure Insertion System -Contract Award | 0.00 | 16-Dec-20 | | 262.00 | 0 | 0 | 0 | 0 | 0 |
| S122600 | Procure Insertion System -Contract/PO - Leadtime | 40.00 | 16-Dec-20 | 12-Feb-21 | 262.00 | 0 | 0 | 0 | 0 | 0 |
| S122700 | Procure Insertion System - Delivery Acceptance | 5.00 | 16-Feb-21 | 22-Feb-21 | 262.00 | 0 | 40000 | 0 | 47,396 | 47,396 |
| | Half detector Assembly Readout and Cooling Test at BNL | 473.00 | 24-Apr-20 | 17-Mar-22 | 0.00 | 1176 | 0 | 59,290 | 0 | 59,290 |
| S123100 | Test RU at BNL | 10.00 | 16-Sep-20 | 29-Sep-20 | 293.00 | 80 | 0 | 12,671 | 0 | 12,671 |
| S123200 | Test FELIX at BNL | 10.00 | 23-Jun-20 | 07-Jul-20 | 352.00 | 80 | 0 | 12,671 | 0 | 12,671 |
| S123300 | Test PS at BNL | 10.00 | 24-Apr-20 | 07-May-20 | 393.00 | 40 | 0 | 3,726 | 0 | 3,726 |
| S123400 | Assemble & Test Cooling System at BNL | 15.00 | 09-Mar-21 | 29-Mar-21 | 202.00 | 160 | 0 | 17,786 | 0 | 17,786 |
| S123500 | Test Half Barrel #1 | 15.00 | 06-Dec-21 | 27-Dec-21 | 0.00 | 168 | 0 | 6,219 | 0 | 6,219 |
| S123600 | Test Half Barrel #2 | 15.00 | 28-Dec-21 | 19-Jan-22 | 0.00 | 168 | 0 | 6,219 | 0 | 6,219 |
| S123700 | MVTX Full System Test at BNL | 40.00 | 20-Jan-22 | 17-Mar-22 | 0.00 | 480 | 0 | 0 | 0 | 0 |
| S123800 | Completed: System Test at BNL | 0.00 | | 17-Mar-22 | 0.00 | 0 | 0 | 0 | 0 | 0 |






Actual Work | Critical Rem. Work | Remaining Work | Actual LoE | Remaining LoE | Milestone