sPHENIX MVTX Cost and Schedule Review Summary

Ming Liu, LANL

July 29-30, 2019

BNL

Presentation Summary

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.

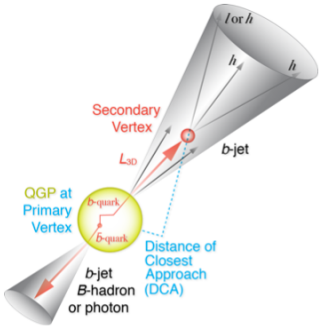
In carrying out this review, the review committee is requested to consider the following questions:

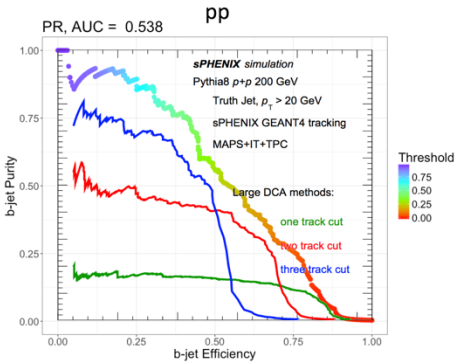
1) Are the costs of the project sufficiently well understood, and are all resources required to successfully complete the project fully identified?
2) Is the schedule of the project sufficiently well understood and matched to the plan for installation in FY22?
3) Are the project risks properly identified 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.

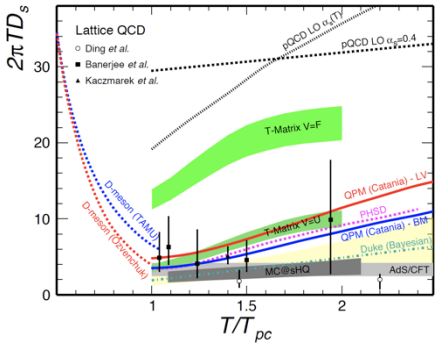
Berndt Mueller
Associate Laboratory Director for Nuclear and Particle Physics

MVTX Enables the 3rd Science Pillar

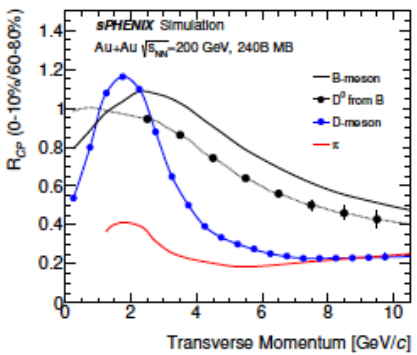


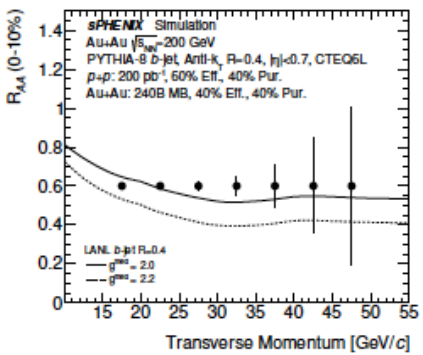


From measurements to physics understandings

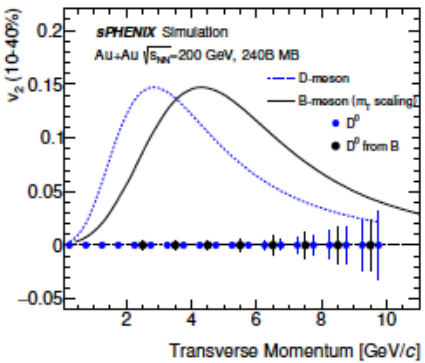


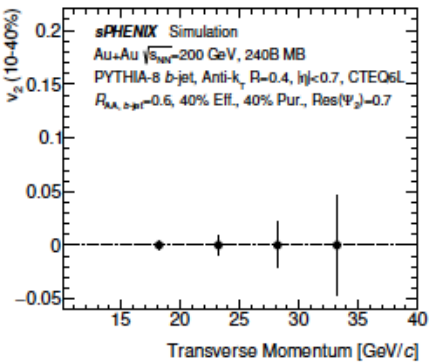
Open heavy flavor hadron & jet modification





Open heavy flavor hadron & jet flow





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)

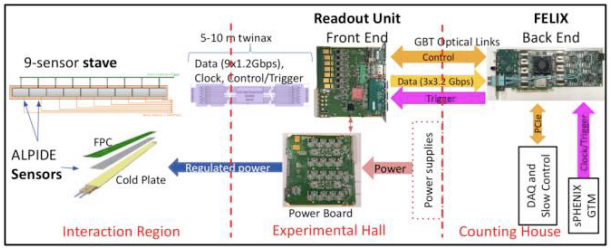
DCA resolution	<50um for charged hadrons (pions) at pT = 1GeV/c
Tracking efficiency	>60% for charged hadrons (pions) at pT = 1GeV/c in the 10% most central Au+Au collisions

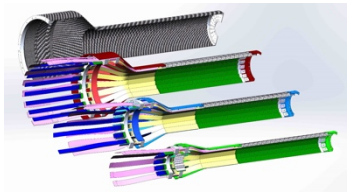
Very Successful R&D

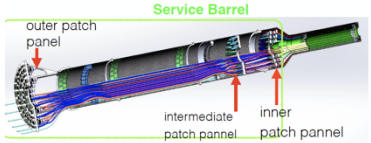
Jo, Cameron, Walt, Camelia, Yuan et al.

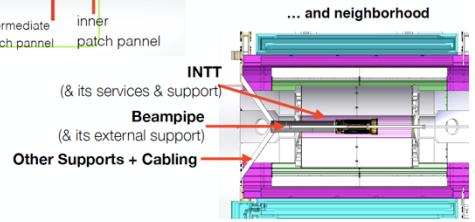
- MVTX sensor/stave & readout integration
  - **Full stave readout chain demonstrated with final electronics RU, PU, FELIX**
  - **Stave modified for better MVTX/INTT integration; MVTX-INTT space-conflict resolved**
  - **Long readout cables tested**
  - **Verify MVTX KPP**

- MVTX mechanical design & system integration
  - **Preliminary detector design completed, 3D mockup demonstrated**
  - **MVTX + INTT/sPHENIX integration design developed**
  - **Assembly and installation plan developed**





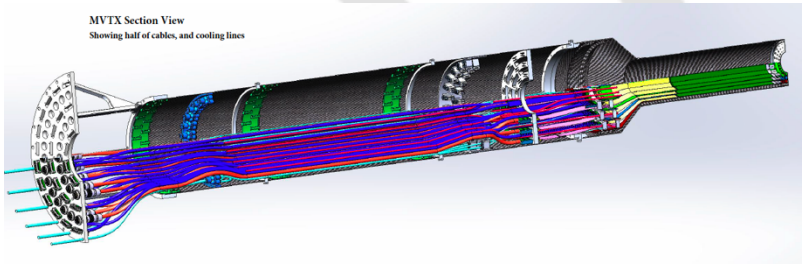




MVTX Deliverables in PMP

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.

Review Charge

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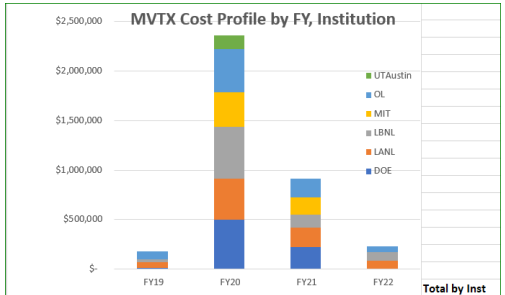
3) Are the project risks properly identified and appropriate mitigation strategies in place, including any risks to sPHENIX operations? Do the cost and schedule estimates include adequate contingency based on sound and reasonable risk analysis?
4) Is the Project Management Plan complete?

1) Are the costs of the project sufficiently well understood, and are all resources required to successfully complete the project fully identified?

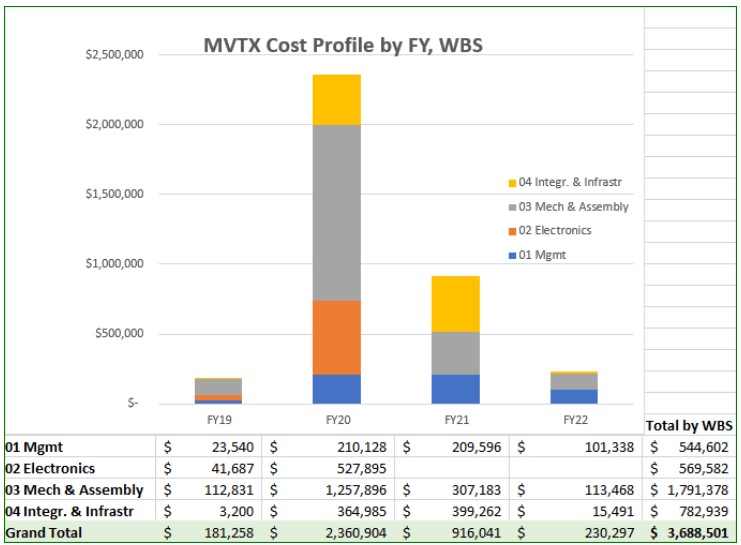
Yes.

All previous talks

- Based on R&D, quotes and experience
- M&S and labor cost profile in P6
  - **Electrical system**
  - **Detector mechanical system**
  - **MVTX mechanical system integration**



	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	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**

		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

2) Is the schedule of the project sufficiently well understood and matched to the plan for installation in FY22?

See Dave and Irina's talks;
and all technical presentations

Yes.

- Based on R&D and experience
- Milestones defined in PMP
- Critical path identified

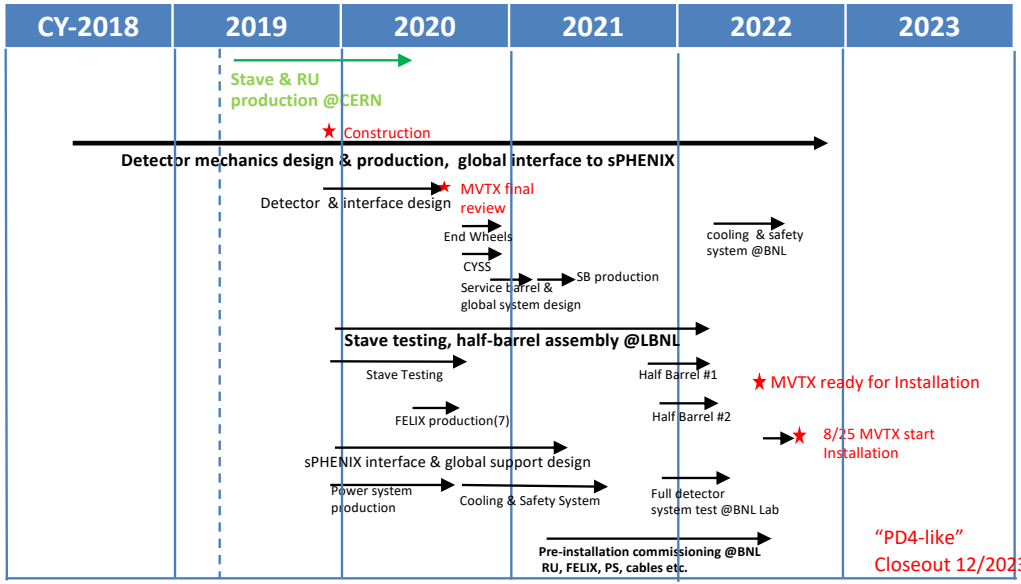


Table 4 Milestones and Key Tasks

Milestone	Date
Start Project	4th Qtr FY2019
SamTec Cables Prod. Contract Awards	3rdQtr FY2020
Felix v2.0 Prod. Contract Awards	2nd Qtr FY2020
All 84 Staves received	4th Qtr FY2020
End Wheel Tooling Design	2nd Qtr FY2020
CYSS Design	2ns Qtr FY2020
Service Barrel Design	3rd Qtr FY2020
MVTX Final Design Review	4th Qtr FY2020
Complete End Wheels	4th Qtr FY2020
Complete CYSS	4th Qtr FY2020
Complete SB	1st Qtr FY2021
Procure Support Structures Contract Awards	1st Qtr FY2021
Half Barrels Assembled	1st Qtr FY2022
MVTX ready for Installation in sPHENIX	2nd Qtr FY2022
Installation Finished	4th Qtr FY2022
Ready for Beam	1st Qtr FY2023
Project Closeout	1st Qtr FY2024

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?

Yes.

- MVTX risk register in sPHENIX
- Major risks identified and mitigation strategies developed

See Dave and Irina's talks;
and all technical presentations

MVTX Risk Register in sPHENIX

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 ($K)	Probability Score	Cost Score (1-4)	Schedule Score	Technical Score (1-4)	Overall Impact Score	EMV K$	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		

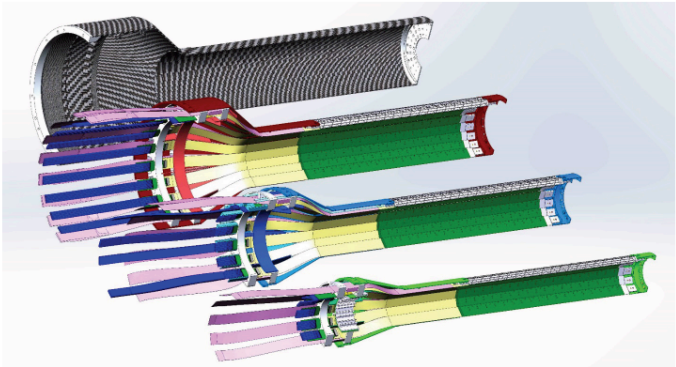
4) Is the Project Management Plan complete?

Yes.

Ming and Dave's talks

- PMP document completed
  - **Project baseline**
    - **Physics**
    - **Functional requirements/KPP/UPP**
    - **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**
- Project fully integrated into sPHENIX P6
  - **Costs, schedules and risk register**

Ready to deliver MVTX on schedule and on budget!



Management Plan

for

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

at the

Brookhaven National Laboratory

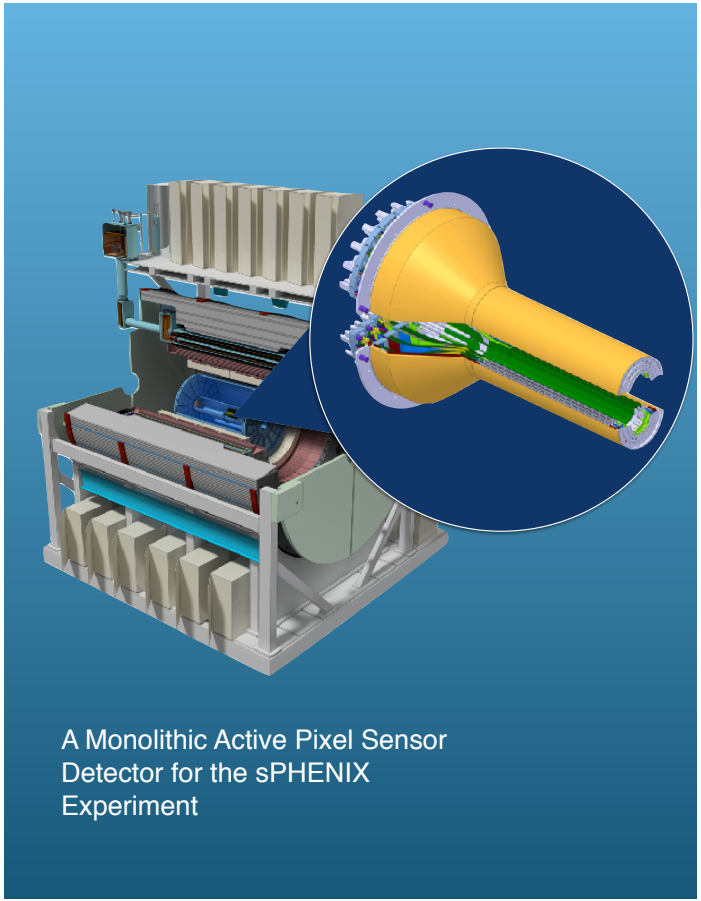
July 26, 2019 (V7)

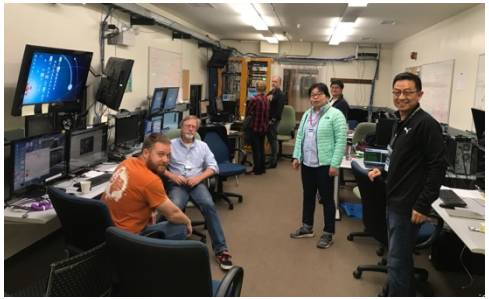
Summary

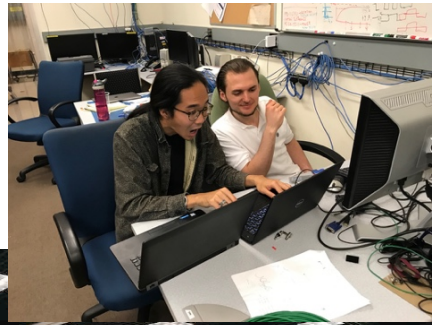
- MVTX is ready to receive fund for the project
  - **Electrical system is ready for production**
  - **Preliminary detector mechanical design completed**
  - **Preliminary sPHENIX mechanical system integration developed**
- LANL LDRD support critical for early key R&D
- Costs, schedules and risk register 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!

Yes, we are ready!





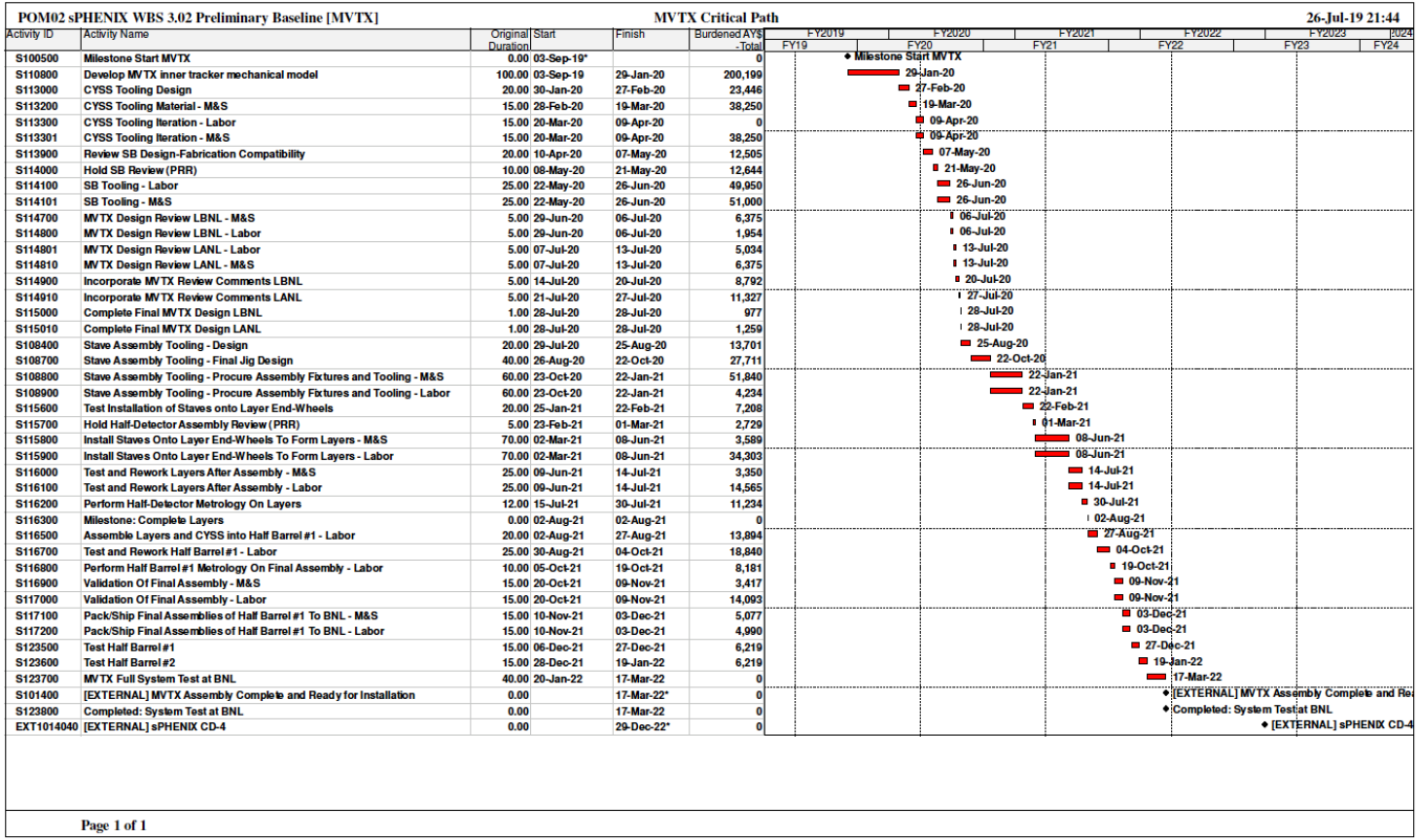


Back Up

MVTX WBS

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

Critical Path



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

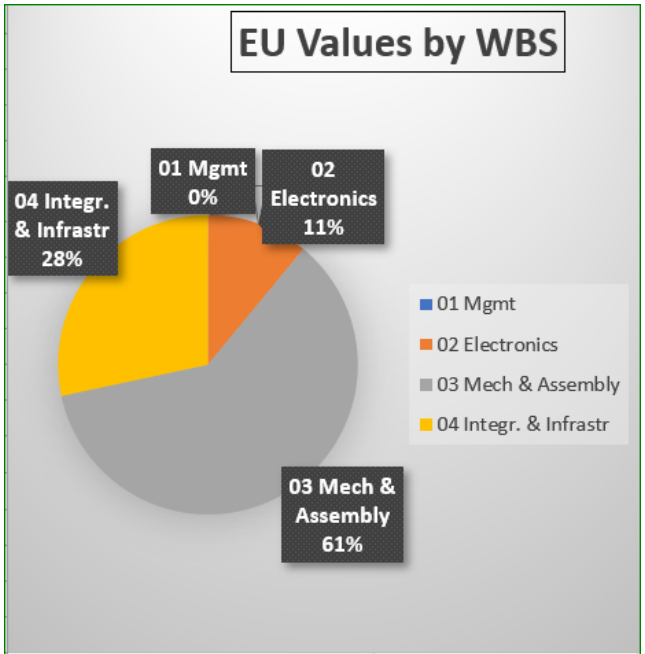
Activity ID	Activity Name	Original Duration	Start	Finish	Burdened AY$ -Total
S100500	Milestone Start MVTX	0.00	03-Sep-19*		0
S110800	Develop MVTX inner tracker mechanical model	100.00	03-Sep-19	29-Jan-20	200,199
S113000	CYSS Tooling Design	20.00	30-Jan-20	27-Feb-20	23,446
S113200	CYSS Tooling Material - 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%**

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		