

MVTX Overview (WBS 3.2)

Ming Liu, LANL

April 9-11, 2019

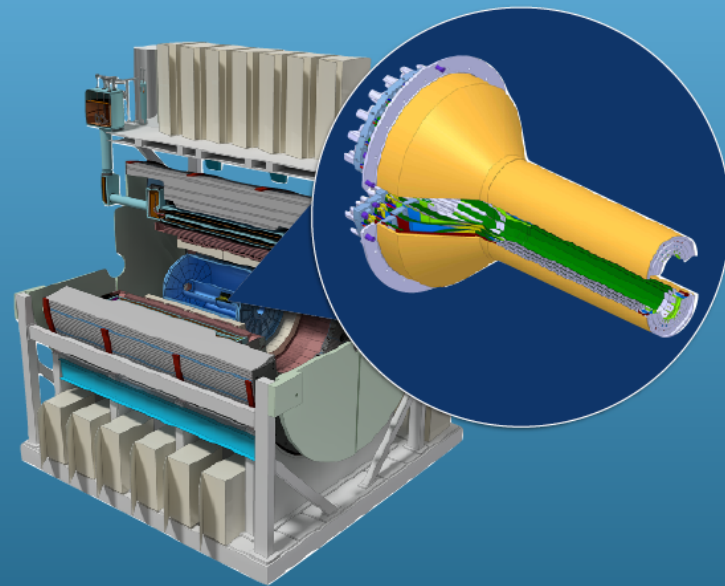
BNL Director's Review

Outline

- MVTX science & technology
- MVTX scope
- Cost & schedule
- Status & highlights
- Issues and concerns

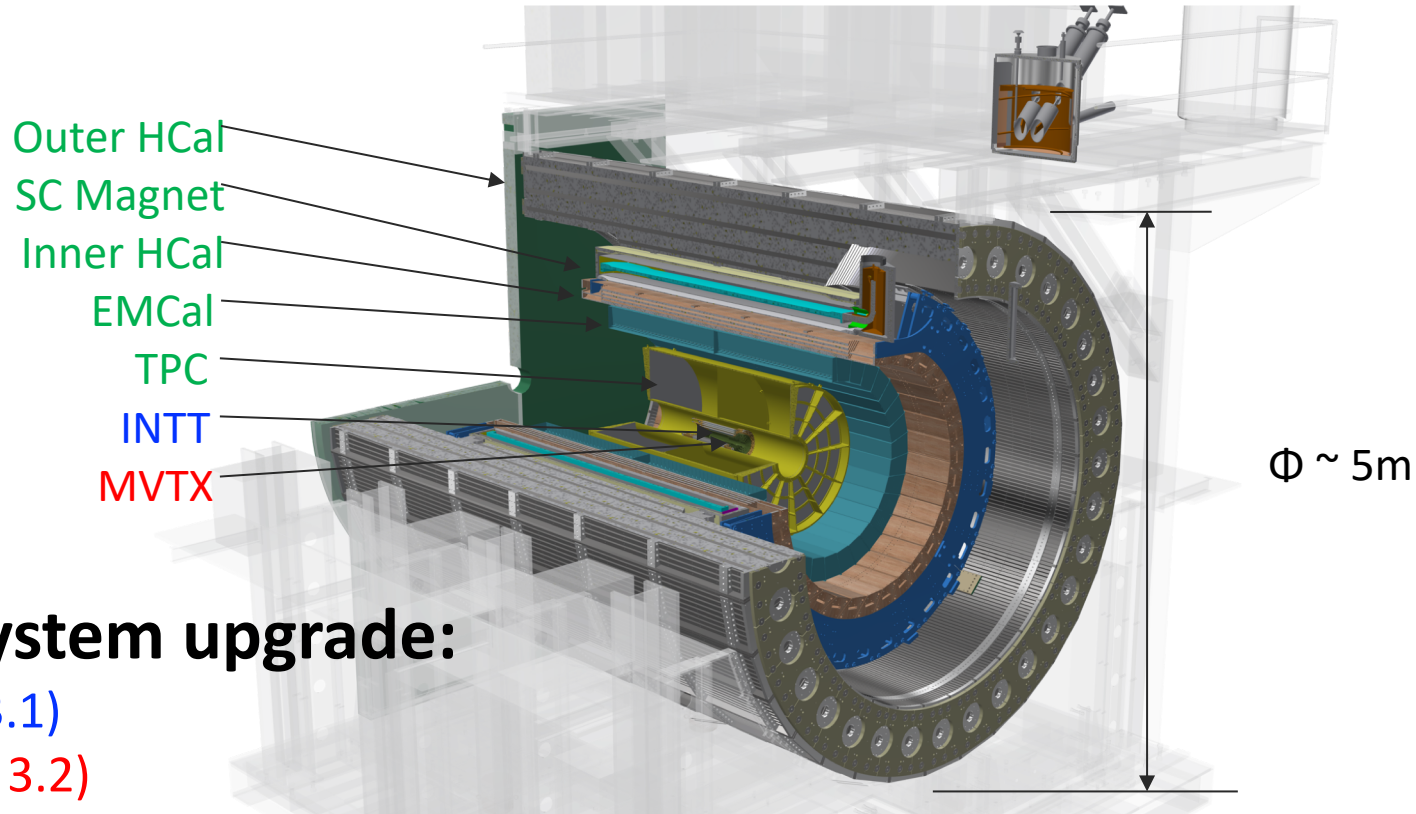
MVTX:
Monolithic-active-pixel-sensor based VerTeX detector

Document: sPH-HF-2018-001
<https://indico.bnl.gov/event/4072/>



A Monolithic Active Pixel Sensor
Detector for the sPHENIX
Experiment

The sPHENIX Detectors



Tracking system upgrade:

- INTT (WBS 3.1)
- MVTX (WBS 3.2)

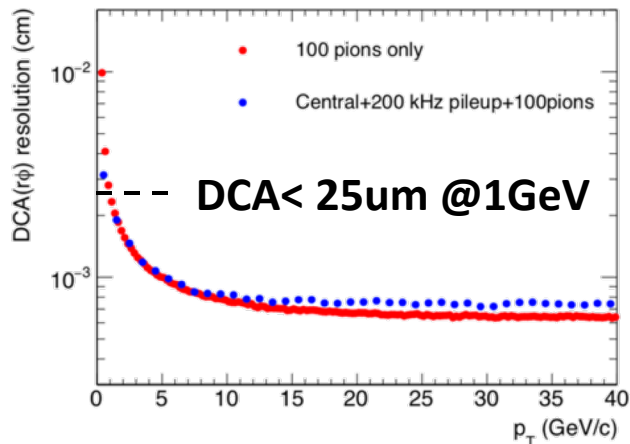
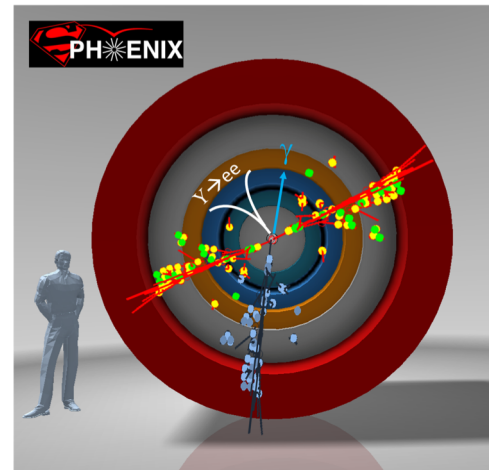
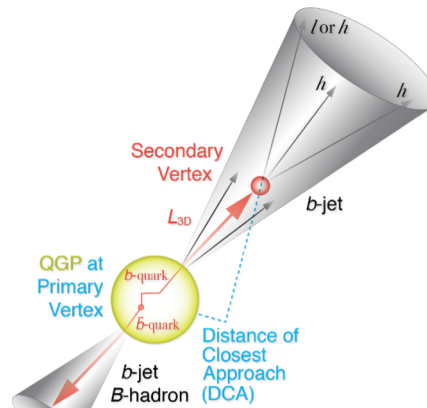
MVTX Enables the 3rd Science Pillar

1. Jets

2. Upsilon

3. Open Heavy Flavor

- Bottom quarks are heavy (4.2 GeV)
- Produced in initial collision, probe QGP evolution
- Well controlled in pQCD
- Access fundamental transport properties of QGP



- Precision tracker + High rate capability
→ Precision bottom observables over wide scales in p+p, p+A and A+A
- Initial observables:
 - **B-meson @ $p_T < 10$ GeV/c**
 - **b-jet @ $15 < p_T < 50$ GeV/c**

MVTX Technical Overview

Ross & Yuan's talks

Service cone: signal, power, cooling
and mechanical support

CYSS: Cylindrical Shell Structure

Extended power FPC

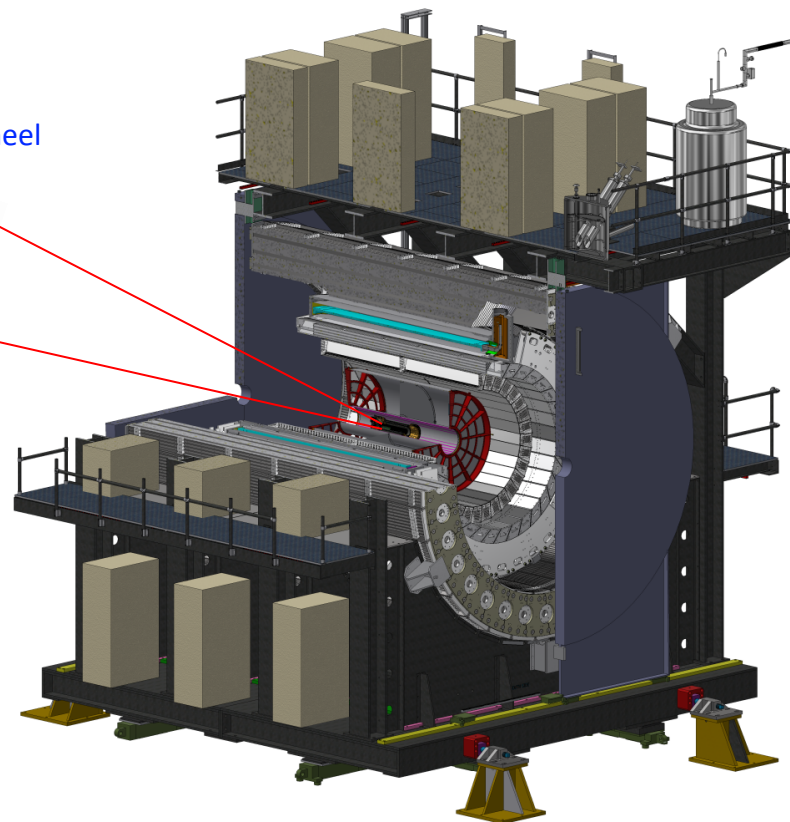
End-Wheel

3-layer sensor barrel
- 48 staves, 432 chips

27cm

MVTX
parameters

	Layer 0	Layer 1	Layer 2
Radial position (min.) (mm)	23.7	31.4	39.1
Radial position (max.) (mm)	28.0	35.9	43.4
Length (sensitive area) (mm)	271	271	271
Active area (cm ²)	421	562	702
Number of pixel chips	108	144	180
Number of staves	12	16	20



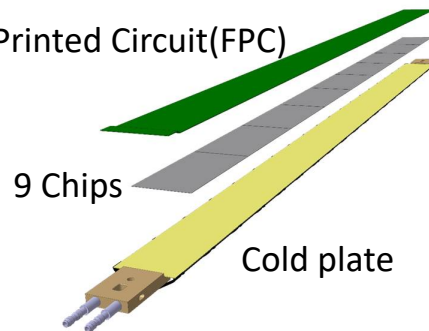
Monolithic Active Pixel Sensors (MAPS)

The Next-Generation, State-of-the-Art Pixel Tracker

Advantages of ALICE Pixel DEtector (ALPIDE) sensor:

- Very fine pitch ($27\mu\text{m} \times 29\mu\text{m}$), for superb spatial resolution
- High efficiency ($>99\%$) and low noise ($<10^{-6}$), for excellent tracking
- Time resolution, as low as $\sim 5 \mu\text{s}$, for less pileup
- Ultra-thin/low mass, $50\mu\text{m}$ ($\sim 0.3\% X_0$), for less multiple scatterings
- 0.5M channels with on-pixel digitization, for zero-suppression and fast readout
- Low power dissipation, $40\text{mW}/\text{cm}^2$, for minimal service materials

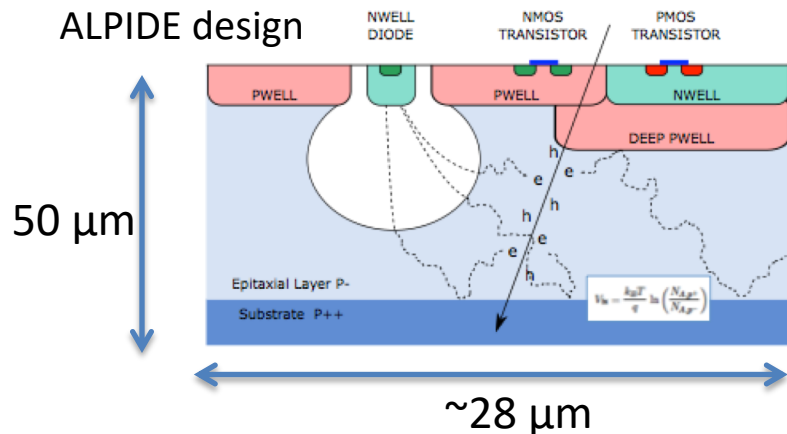
Flexible Printed Circuit(FPC)



An ideal detector for QGP physics!

A 9-chip MAPS stave, 1.5cm x 27cm

ALPIDE design



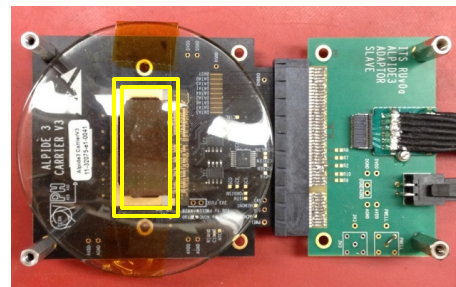
Tower Jazz 0.18 μm CMOS

- 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: $N_A \sim 10^{16}$

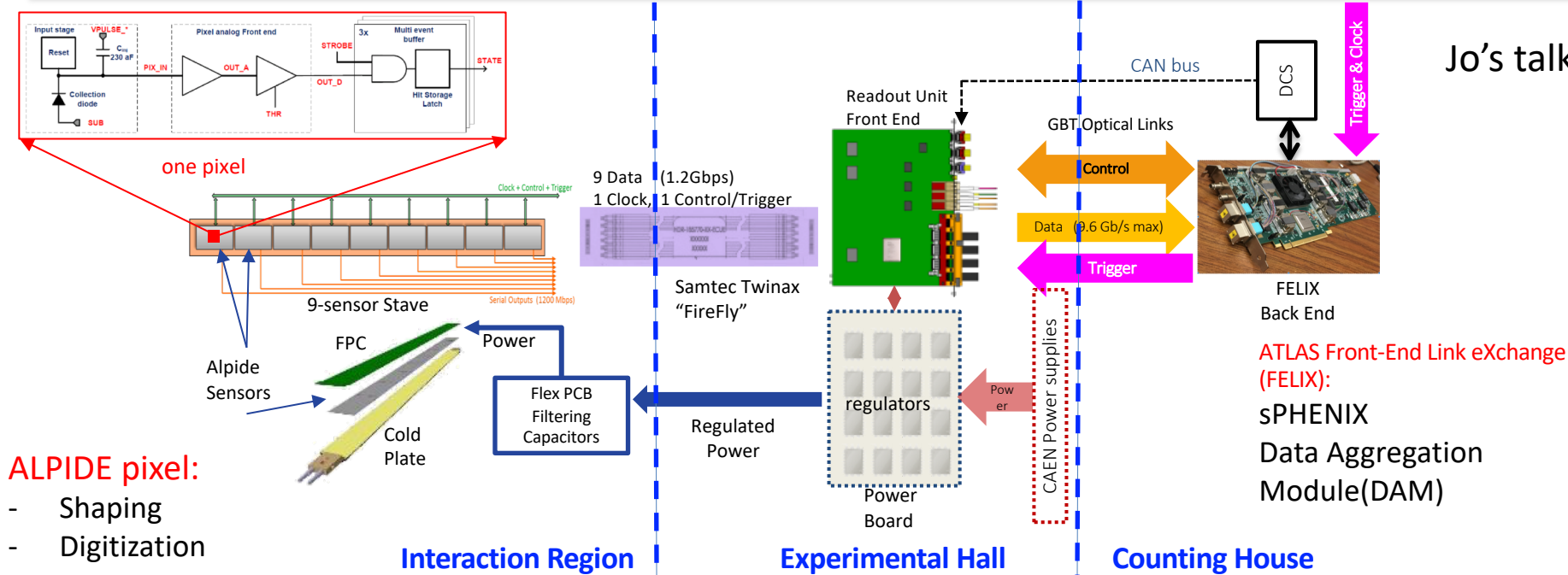
ALPIDE sensor:

1.5cm x 3.0cm, 0.5M pixels



MVTX Readout, Power and Controls

Jo's talk



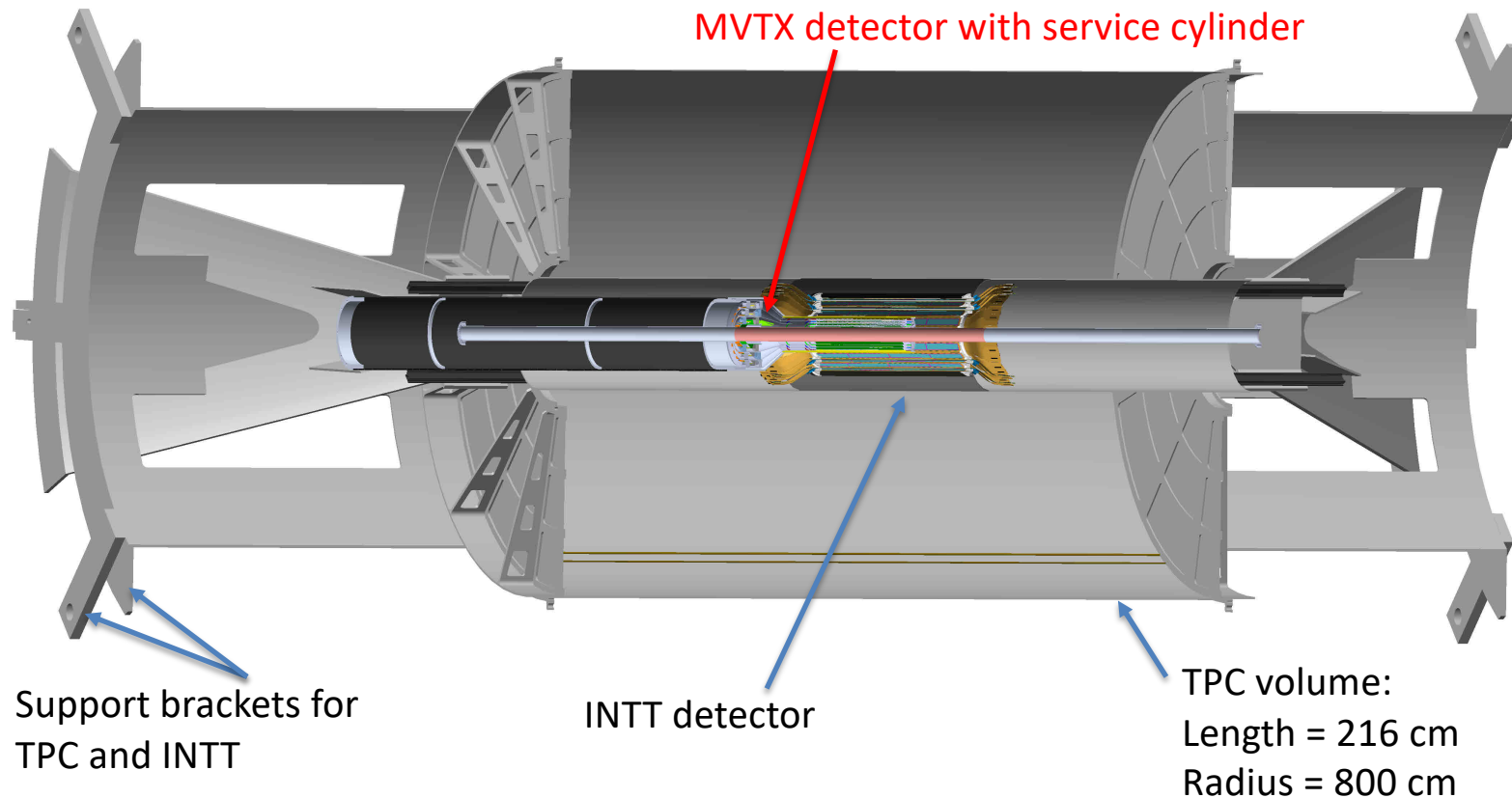
ALPIDE pixel:

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

MVTX Detector Electronics consists of three parts

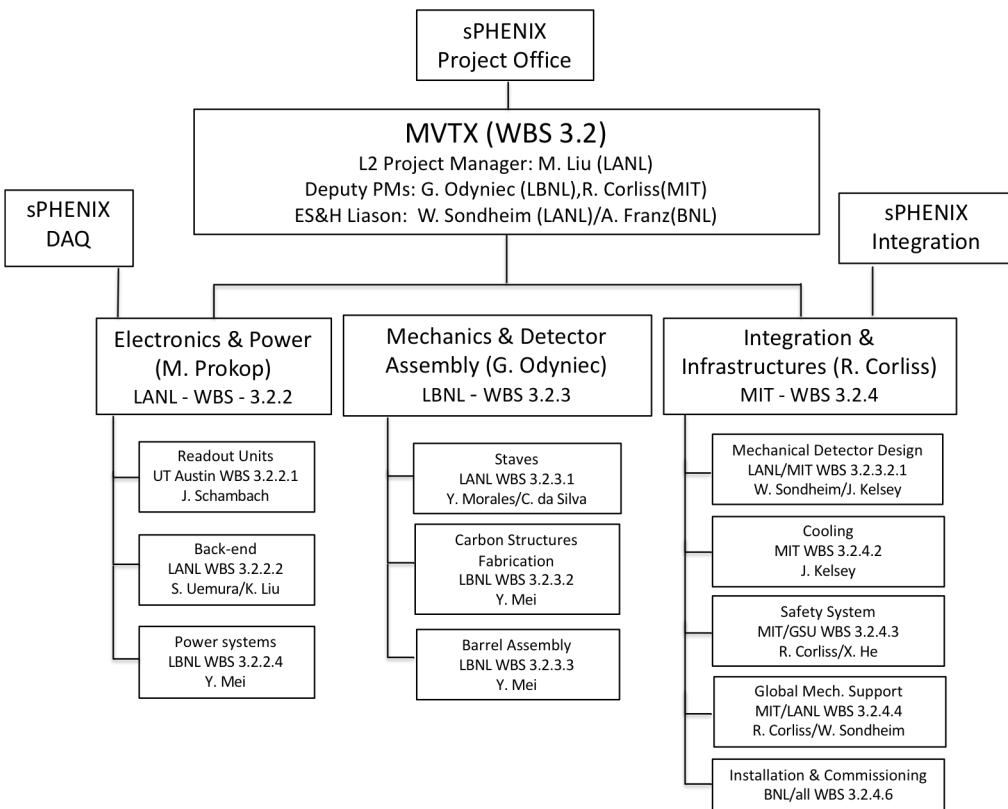
Sensor-Stave (9 ALPIDE chips) | **Front End**-Readout Unit | **Back End**-FELIX/DAM

MVTX Detector in sPHENIX



- Mechanical structure design
 - Design & FEA, LANL/MIT
 - End Wheels
 - Cylindrical structure shells
 - Detector service half barrels
 - Service patch panels
 - Global interface
 - Mechanical structure fabrication
 - Composite structures, LBNL
 - Non-composite structures, MIT
 - Installation tooling etc., MIT/LANL/LBNL/BNL
 - Ancillary systems – “adopt” ALICE/ITS
 - Cooling plant, MIT/BNL
 - Slow control & monitoring etc., MIT/GSU
 - MVTX electronics
 - Backend FELIX and cables
 - Integration into sPHENIX DAQ
 - Power system
 - Detector assembly & test
 - Stave QA & half detector assembly @LBNL
 - System test & integration @LBNL/BNL
 - Installation & commissioning, by all
 - Pre-installation commissioning @BNL
 - Installation @IR
- Early generic R&D accomplished through LANL LDRD
- Readout integration
 - Detector conceptual design

MVTX Collaborators & Institution Roles



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.

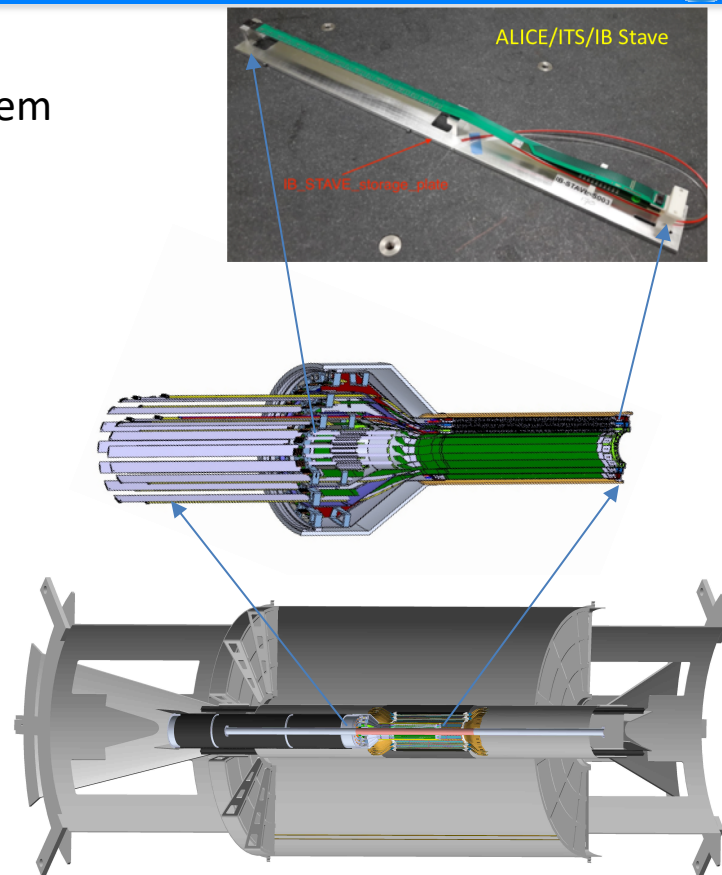
Sun Yat-Sen University (SYSU/China) : MVTX detector and physics simulations.

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

Schedule Drivers

- Budget availability
 - Final engineering design of the mechanical system
 - Production of support structures
- Mechanical structures
 - Detector and interface system design
 - Carbon structure fabrication
- Detector assembly and test
 - Assembly jigs design and fabrication
 - Detector assembly & QA
 - Metrology
- Final installation in IR
 - Last detector to be installed



Cost Drivers

MVTX Budget by L3 in AYk\$			Burdened /Esc.	
WBS	Level 2 WBS Description	OPC	TEC	Total
3.2.01	Project Management	\$0	\$642	\$642
3.2.02	Electronics	\$0	\$665	\$665
3.2.03	Mechanics and Assembly	\$0	\$2,001	\$2,001
3.2.04	Integration and Installation	\$0	\$1,023	\$1,023
	Sub-total	\$0	\$4,331	\$4,331
	Contingency	\$0		\$0
	Total Project Cost	\$0	\$4,331	\$4,331

Mechanical design and fabrication

- CYSS
- End wheels
- Service barrel
- Global interface

Basis of Estimate & Resource-Loaded Schedules

- Electronics: production
 - FELIX: ATLAS/sPHENIX production, LANL/LDRD
 - RU services, cables: ALICE/ITS production, LANL/LDRD
 - Power boards: ALICE/ITS production, LANL/LDRD
 - CAEN bulk PS: Quotes from CAEN, ALICE/ITS production, LANL/LDRD
- Mechanics & Integration: design and production
 - CYSS, End wheels, Service barrel: ALICE/ITS
 - Integrations: Recent experience at RHIC, HFT/STAR, FVTX/PHENIX

WBS Number: 3.2.2.3 Backend Electronics - FELIX

MVTX BoE Doc

Technical scope:

This item contains all the backend readout electronics FELIX boards required for MVTX readout.

Work statement:

Produce 8 FELIX boards to integrate MVTX readout electronics into the sPHENIX DAQ system.

Assumptions used in developing estimate:

We will use the ATLAS FELIX v2.0 PCIe board developed by the BNL group for the ATLAS upgrade. The FELIX board production quote for sPHENIX was obtained in 2018, about \$8K per board. A total of 8 FELIX boards (6 + 2 spares) are required for MVTX.

Cost Summary:

Total (K)	M&S	Labor	Contingency (average)
122	103	19	25%

BROOKHAVEN NATIONAL LABORATORY sPHENIX MVTX Project Detailed Schedule Budgeted Cost Included Data Date: 01-Oct-18 Published: 02-Apr-19 12:38													
Activity ID	Activity Name	CAM	At Compl. Duration	Start	Finish	Total Float	Hours	Direct FY19	M&S	Burd APS - Labor	Burd APS - M&S	Burd APS - Total	
S110400	ship from CERN to LBNL - Batch 1	Liu, Ming	7	27-Jun-19	08-Jul-19	318	0	600	\$0	\$7,500	\$7,500	\$7,500	
S110500	ship from CERN to LBNL - Batch 2	Liu, Ming	7	25-Sep-19	03-Oct-19	268	0	600	\$0	\$7,564	\$7,564	\$7,564	
S110600	ship from CERN to LBNL - Batch 3	Liu, Ming	7	27-Dec-19	07-Jan-20	219	0	600	\$0	\$7,650	\$7,650	\$7,650	
S110700	ship from CERN to LBNL - Batch 4	Liu, Ming	7	27-Mar-20	06-Apr-20	169	0	600	\$0	\$7,650	\$7,650	\$7,650	
POM028_3.02.3.02.03.02	Carbon Structures		741	01-Apr-19	17-Mar-22	0	5774	368511	\$910,025	\$472,154	\$1,382,179		
POM028_3.02.3.02.03.02.01	Mechanics Detector Design		80	01-Apr-19	23-Jul-19	0	640	0	\$167,952	\$0	\$167,952		
S110800	Develop MAPS inner tracker mechanical model	Liu, Ming	80	01-Apr-19	23-Jul-19	0	640	0	\$167,952	\$0	\$167,952		
POM028_3.02.3.02.03.02.02	End Wheels		277	24-Jul-19	28-Aug-20	54	502	72000	\$73,964	\$90,875	\$164,839		
S110900	Design End-wheels	Liu, Ming	15	24-Jul-19	13-Aug-19	54	120	0	\$36,658	\$0	\$36,658		
S111000	Prototype End-wheels - M&S	Liu, Ming	30	14-Aug-19	25-Sep-19	54	0	10000	\$0	\$12,500	\$12,500		
S111100	Prototype End-wheels - Labor	Liu, Ming	30	14-Aug-19	25-Sep-19	54	12	0	\$2,305	\$0	\$2,305		

Carbon Structures

Labor, M&S

POM02B_3.02.3.02.02.02	FELIX 2.0	254	01-Apr-19	03-Apr-20	392	186	88400	\$18,588	\$103,640	\$122,229	
S103000	Produce Felix 2.0 first production unit - Labor	Liu, Ming	57	01-Apr-19	19-Jun-19	218	16	0	\$307	\$0	\$3,073
S103100	Procure Optical Fiber - Labor	Liu, Ming	121	01-Apr-19	19-Sep-19	414	2	0	\$307	\$0	\$307
S103200	Produce Felix 2.0 first production unit - M&S	Liu, Ming	57	01-Apr-19	19-Jun-19	218	0	20000	\$0	\$22,778	\$22,778
S103300	Procure Optical Fiber - M&S	Liu, Ming	121	01-Apr-19	19-Sep-19	414	0	50	\$0	\$63	\$63
S103400	Test/QA 1st Felix Unit and Fibers	Liu, Ming	10	20-Sep-19	03-Oct-19	414	40	0	\$0	\$0	\$0
S103500	Procure 7 Felix 2.0 Remaining Units - Provide Requirements to Procurement	Liu, Ming	5	06-Nov-19	13-Nov-19	392	6	0	\$1,187	\$0	\$1,187
S103600	Procure 57 Optical Fiber Sets - Labor	Liu, Ming	20	06-Nov-19	06-Dec-19	462	2	0	\$396	\$0	\$396
S103700	Procure 57 Optical Fiber Sets M&S	Liu, Ming	20	06-Nov-19	06-Dec-19	462	0	2850	\$0	\$3,634	\$3,634

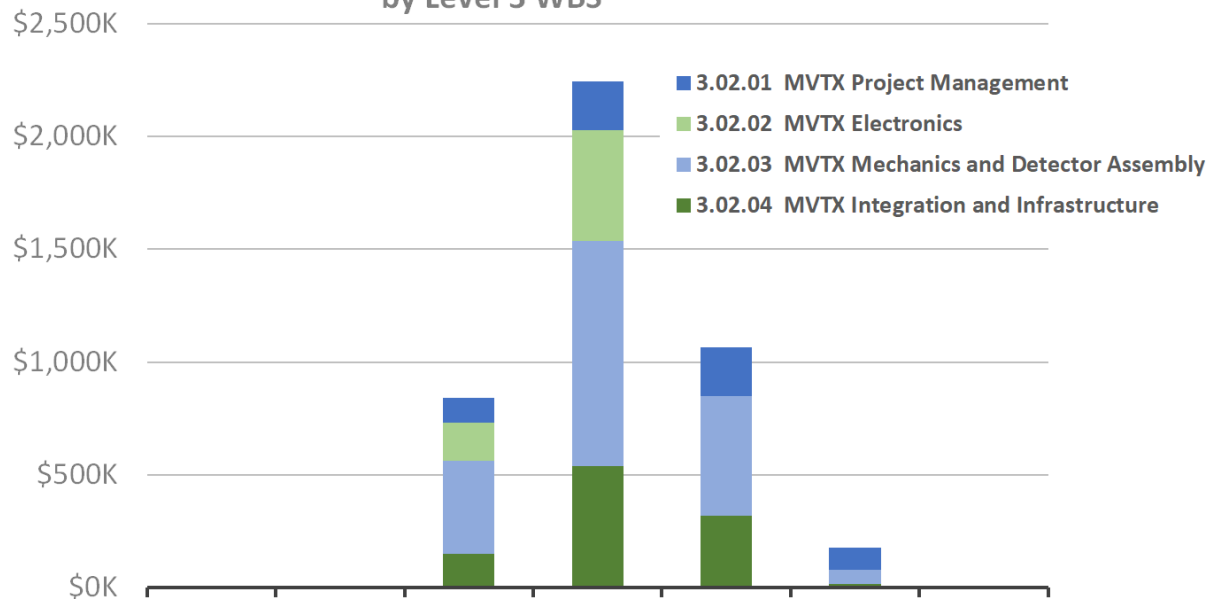
FELIX

Labor, M&S

Resource Distribution

MVTX in P6

Summary MVTX Labor + M&S Cost Profile in Burdened At-Year \$
by Level 3 WBS



WBS Code and Name	FY17	FY18	FY19	FY20	FY21	FY22	FY23	Burdened AY\$	Direct FY19\$
3.02.01 MVTX Project Management			\$ 110,219	\$ 216,751	\$ 216,269	\$ 98,244		\$ 641,483	\$ 373,537
3.02.02 MVTX Electronics			\$ 171,762	\$ 493,205				\$ 664,967	\$ 506,824
3.02.03 MVTX Mechanics and Detector Assembly			\$ 409,513	\$ 997,208	\$ 529,814	\$ 64,163		\$ 2,000,698	\$ 1,289,696
3.02.04 MVTX Integration and Infrastructure			\$ 150,963	\$ 538,325	\$ 317,878	\$ 15,892		\$ 1,023,058	\$ 651,708
Grand Total			\$ 842,457	\$ 2,245,489	\$ 1,063,961	\$ 178,298		\$ 4,330,205	\$ 2,821,765

MVTX Schedules and Milestones sPHENIX



sPHENIX:

★ CD1/3a

★ PD2/3

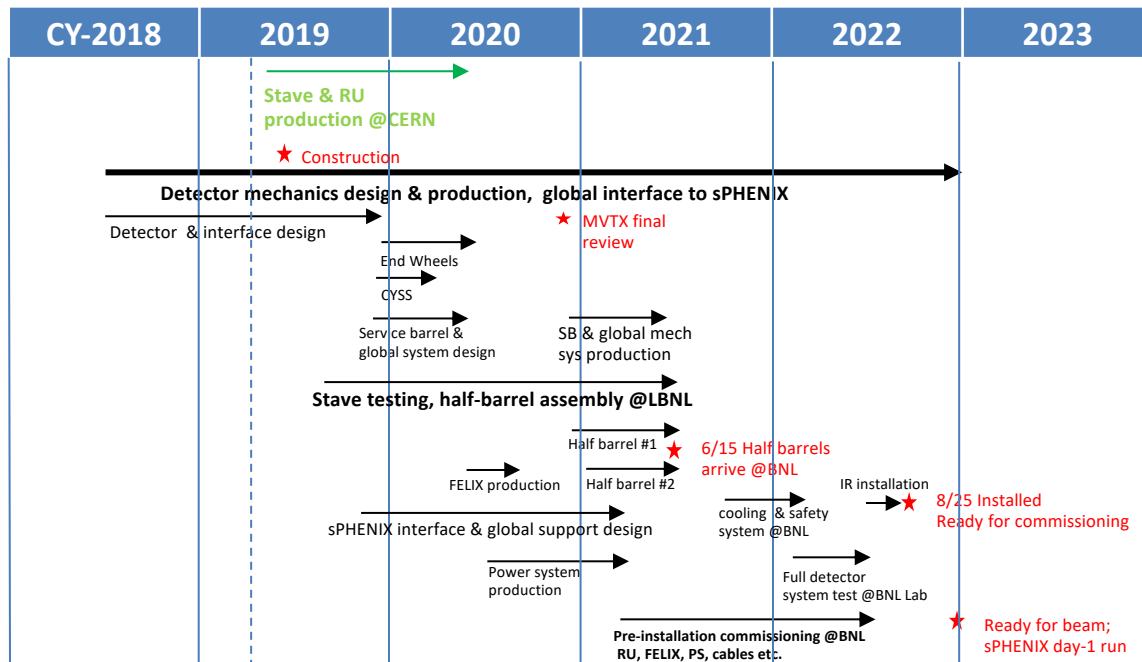
★ Installation

★ 1st collisions

Generic R&D
Sensors for RHIC

MVTX

Feb. 2019, in P6



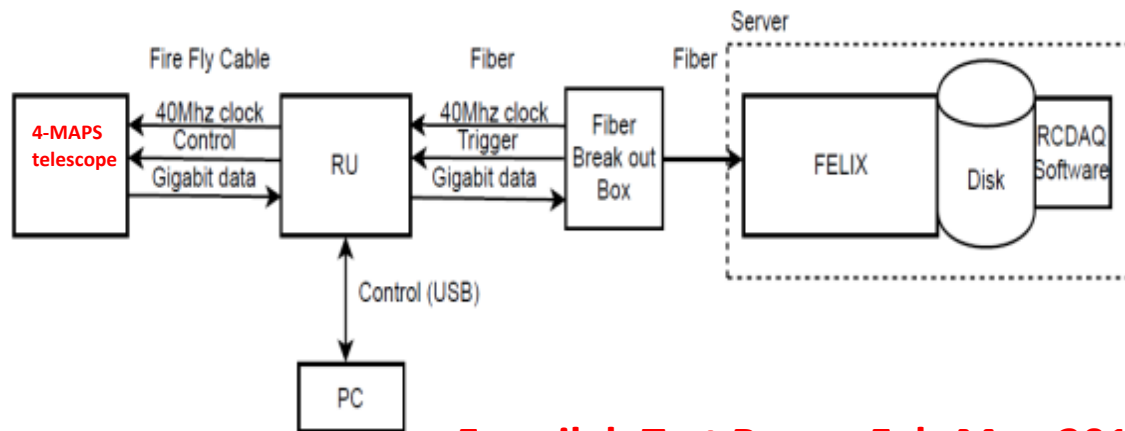
Today

Status and Highlights

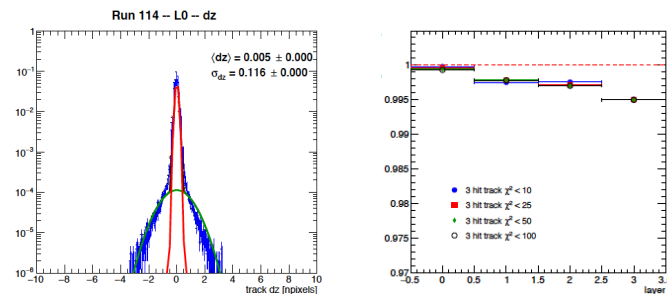
- Full readout chain demonstrated through LANL LDRD
 - Successful Fermilab Test Beam run in 2018
- Modified stave certified through LANL LDRD
 - Successfully tested at CERN
 - Radiation hardness verified at CERN
- Mechanical system integration MVTX+INTT
 - sPHENIX tracking optimized with 2-layer INTT configuration
 - Mechanical design being updated and 3-D mockup demonstrated
- Readout cables
 - BNL approved the use of SamTec non-Halogen-free cables
 - Electrically better & mechanically compact
 - ALICE confirmed performance with 8m long Halogen-free cables
 - For MVTX, ~10m very likely work (30AWG/sPHENIX vs 32AWG/ALICE)
 - Samples (6.5 ~ 11.5m long) ordered for R&D test at LANL
 - To be tested in coming months



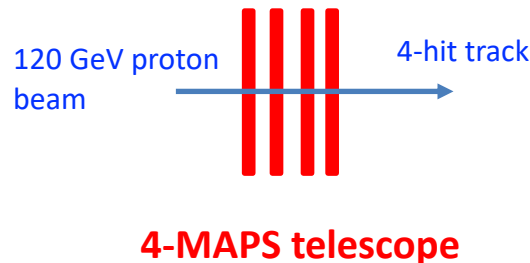
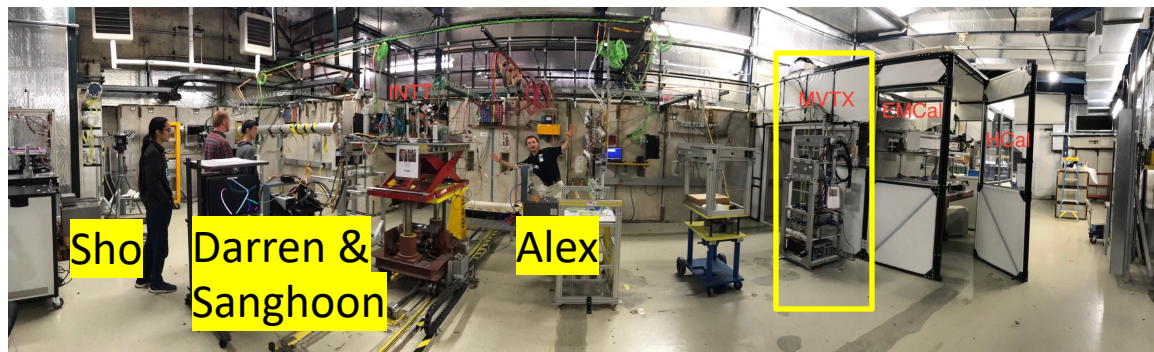
MVTX Full Readout Chain Demonstrated (3/2018) SPHENIX



Fermilab Test Beam: Feb-Mar, 2018

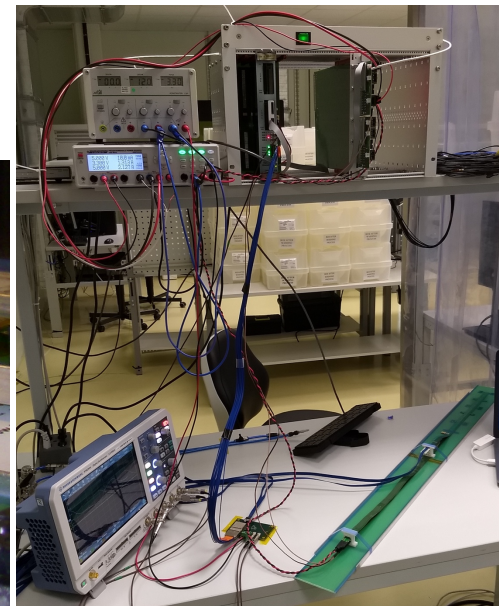
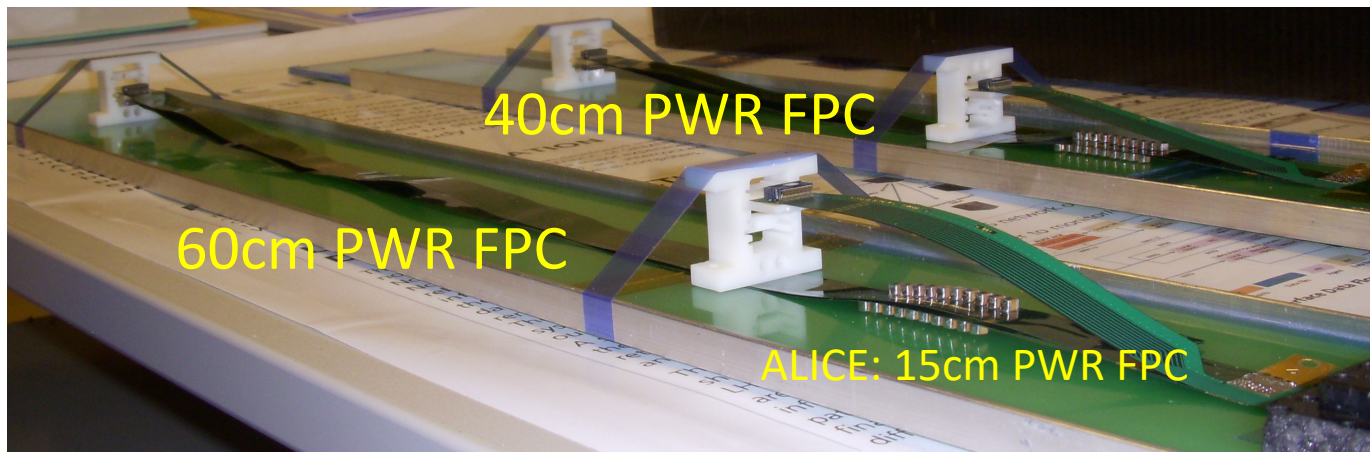


- Tracking spatial resolution: $< 5 \mu\text{m}$
- Hit efficiency: $> 99.5\%$



Confirmed HIC with Extended 40(60)cm Power FPC sPHENIX

- Built and tested two HICs at CERN in 9/2018
 - No change in sensor performance (noise, threshold) observed, as expected;



Followed identical ALICE IB QA test procedure, with a 8m SamTec cable!

Sensor Irradiation Test – OK at 2.7MRad

- Continuous effort by ALICE (@NPI, Czech)
- BNL Director's review recommendation:
 - **Test sensors up to 1MRad**

ALICE/ITS report: 2.7 MRad

<https://indico.cern.ch/event/758048/>

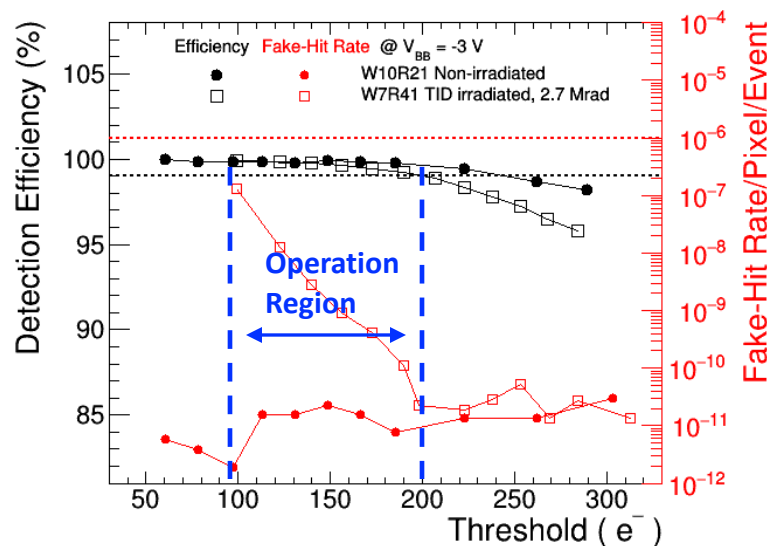
Conclusion

Irradiated ALPIDE sensor (2700 krad) over a large range of threshold settings

has :

- 1) good efficiency up to threshold ~ 190 e (lthr = 100 DAC units)
at $V_{bb} = -3$ V, $V_{casn} = 90$, $V_{casn2} = 102$
- 2) fake hit rate remains orders of magnitude smaller than the requirement ($<< 10^{-6}$)

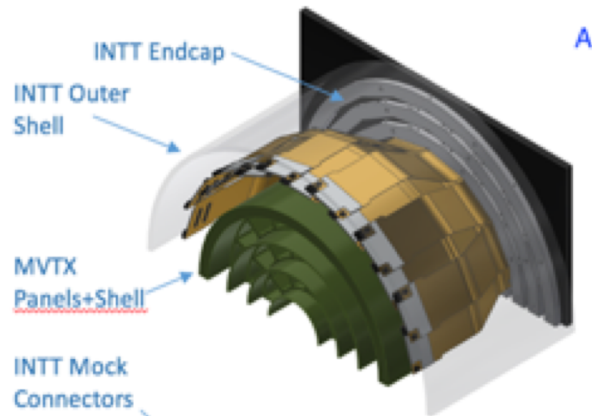
Irradiated chip#41 (2.7Mrad) : efficiency & fake hit rate



red line - fake hit rate- sensitivity limit of ALPIDE
black line - efficiency - the project goal (99%)

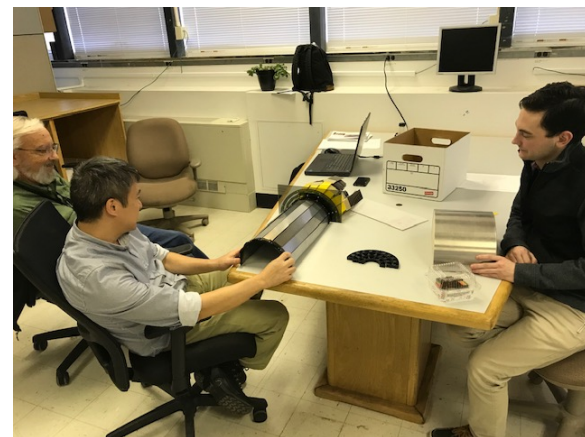
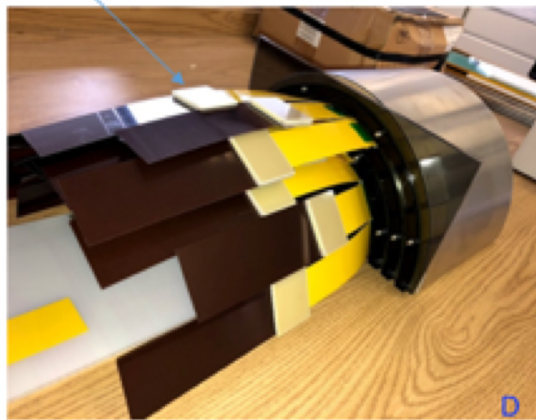
For non irradiated 2 noisy pixels were masked out.
No pixel was masked out for the 2.7Mrad chip.

MVTX + INTT 3-D Mockup (11/2018)



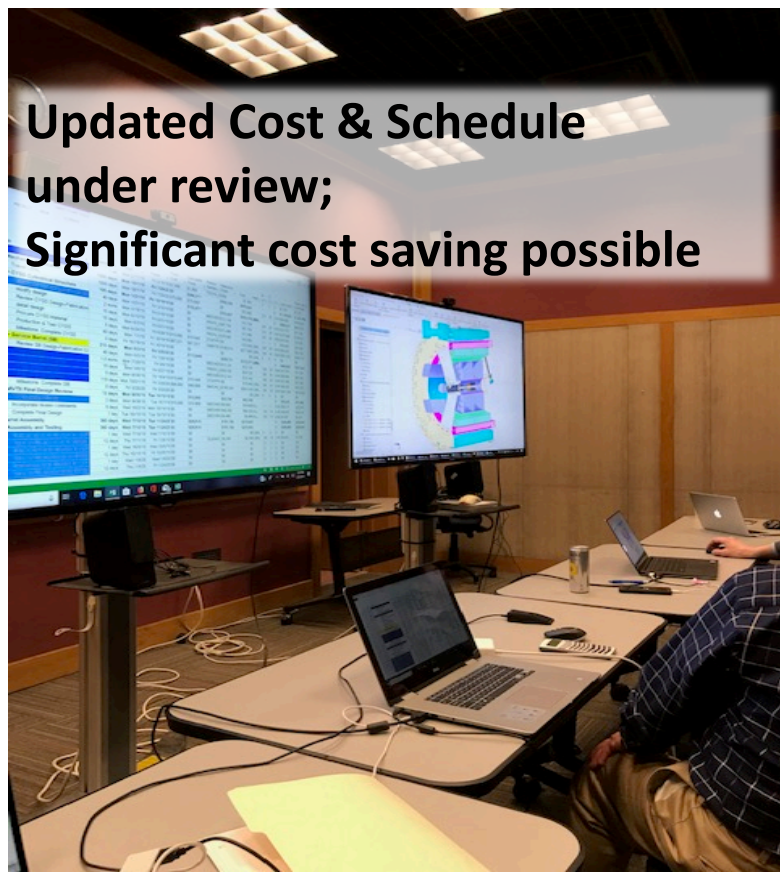
Office of System Integration
– led by Mickey & Bob,
a team of engineers and physicists

MVTX and INTT
Space conflict resolved!



Latest Project Update: MVTX Workshop

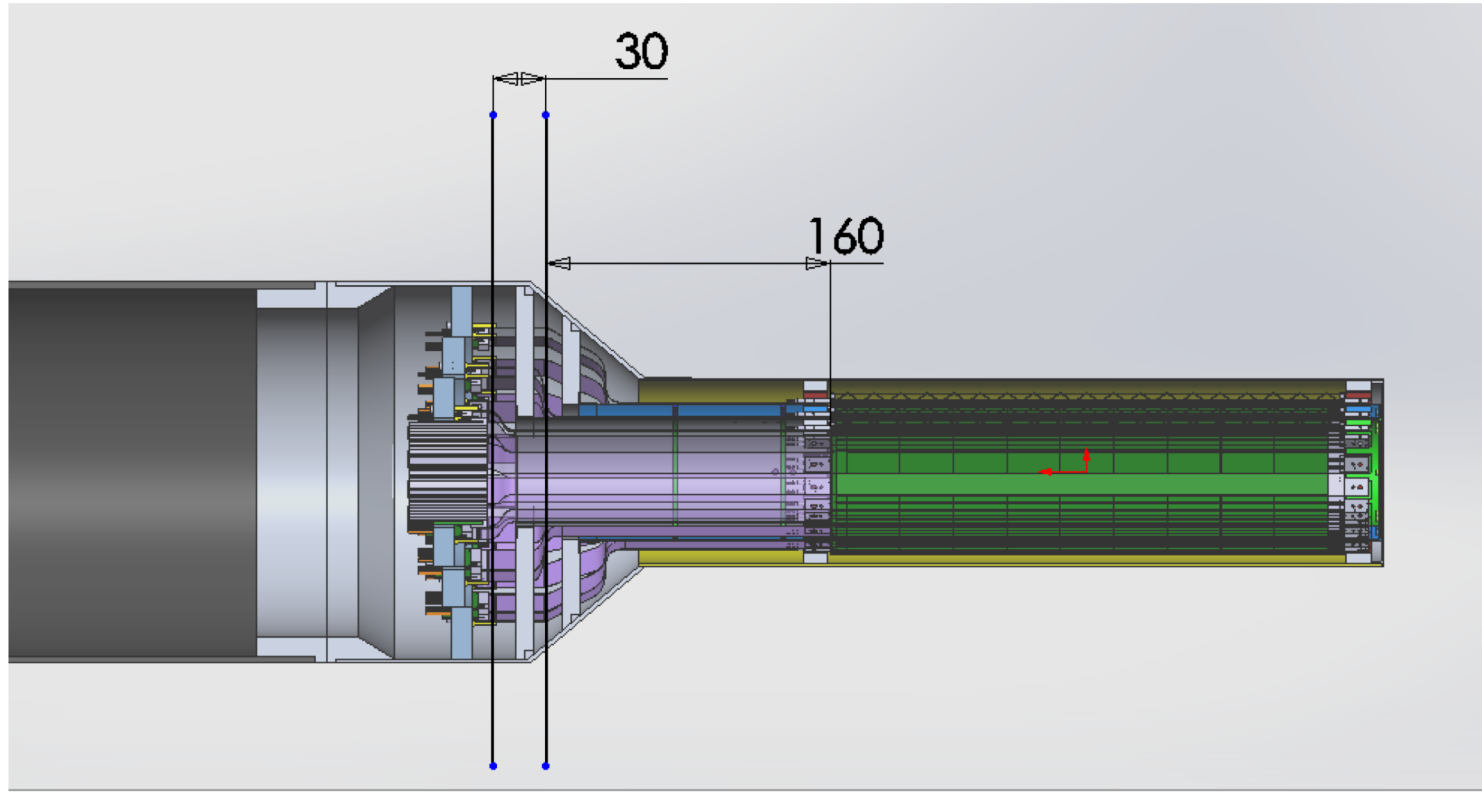
Feb. 28 – Mar. 2, 2019, MVTX/HF Workshop @LBNL



Carbon Structures – Work in Progress

Ross' talk

- Conical sectors are expensive!
- A new design under development to avoid the conical structures, MIT/LANL



Issues and Concerns

- Budget availability
 - Funding for final mechanical system design work
 - Early R&D to reduce high production contingency
 - Preparation for Stave acceptance test/QA/storage at LBNL (3 months lead time)
 - Schedule is closely tied to the funding level
- Carbon structures
 - Cost and schedule, high contingency in cost
 - Window of opportunity at LBNL before ATLAS production
 - Other possible production sites (Italy, France, Korea ...)
- Mechanical system integration
 - sPHENIX beam pipe modification, under discussion with CAD
 - Readout cables, cooling etc.
 - MVTX+INTT+TPC... global support structure design

- MVTX enables the 3rd science pillar
- MVTX detector design & construction
 - As a separate upgrade project from the baseline sPHENIX MIE
 - Engineering design work in progress, MIT/LANL/LBNL et al
 - **Need budget now for the final engineering design work**
 - Construction and assembly work planned for late 2019
- Project integrated into the sPHENIX P6
 - Latest Cost & Schedule under review, significant cost saving possible
 - To be implemented in P6 after this review
- Successful generic R&D through LANL LDRD support
 - Readout integration
 - Stave modification
 - Mechanical system conceptual design
- MVTX is ready to receive project funding

backup



Stave and RU procurement readiness

- Completed sensor/HIC/stave evaluations at CERN
 - Built, tested and confirmed two HICs with 40cm and 60cm long power FPC
 - Sensors irradiated up to 2.7MRad, no issues (updated 9/18/2018).
- Addressed all recommendations on stave/sensor R&D

https://docs.google.com/document/d/1vsm_G7ZLgqv-kBZqK0jF69T_Nx2Uwk0Zxv86jRVxybw/edit?usp=sharing

Cost are set for staves & RUs, procurement through US-ALICE/UTK

- Technical specs document completed for production, BNL/DOE agreed
- sPHENIX RU and stave production starts ~May 2019
- MVTX/INTT mechanical integration
 - Mechanical design being updated and 3-D mockup demonstrated
 - Inner tracking task force completed evaluation, preferred INTT-layers =2
- Readout cables
 - BNL approved the use of SamTec blue cables
 - Electrically better & mechanically compact
 - ALICE confirmed signal performance with 8m long readout cables. For MVTX, 10m very likely works (30AWG/sPHENIX vs 32AWG/ALICE), to be confirmed by on-going R&D at LANL
 - Samples ordered for system integration mockup and test

Stave and RU Production QA Plan Documents Available



<https://indico.bnl.gov/event/4729/>

Staves

- Purchase 84 staves from ALICE/CERN
 - **48 + 28(spares for 2 inner layers) + 8 spares**
 - **Production following the completion of ALICE ITS/IB**
 - **Starting ~Oct. 2018, will last 6-12 months**
 - **Fully tested at CERN before shipping to US**
 - All Gold/Silver staves (same as ALICE IB)
 - A LANL postdoc (Dr. Yasser Morales) oversees production QA at CERN
- Acceptance QA at LBNL
 - **Full test and QA**
 - Electrical
 - Mechanical
 - **Detector assembly at LBNL**

Readout Units

- Purchase 60 RUs from ALICE/CERN
 - **48 + 12 spares(20%)**
 - **To be part of ALICE production**
 - Cost saving
 - Minimize technical risks
 - **Initial test at CERN**
- Acceptance QA at UT-Austin
 - **Full test**
 - **LANL as the 2nd test site**

MVTX in P6 (fully Burd. & Esca.)



<div><div><div>BROOKHAVEN</div><div>NATIONAL LABORATORY</div></div><div>sPHENIX MVTX Project Detailed Schedule</div><div>Budgeted Cost Included</div><div>Data Date: 01-Oct-18 Published: 02-Apr-19 12:38</div></div>												<div><div><div>sPHENIX</div></div></div>									
Activity ID	Activity Name	CAM	At Compl. Duration	Start	Finish	Total Float	Hours	Direct FY19\$-M&S	Burd AYS- Labor	Burd AYS- M&S	Burd AYS- Total	2015	2016	2017	2018	2019	2020	2021	2022		
												FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22		
POM028_3.02	POM02 sPHENIX WBS 3.02 Preliminary Baseline [MVTX]		1281	01-Feb-17 A	17-Mar-22	0	26695	1266751	\$2,760,452	\$1,569,754	\$4,330,205										
POM028_3.02.3	Silicon Detectors		1281	01-Feb-17 A	17-Mar-22	0	26695	1266751	\$2,760,452	\$1,569,754	\$4,330,205										
POM028_3.02.3.00	(Temporary) External Placeholder Milestones in WBS 3x		1169	01-Feb-17 A	01-Oct-21	112	0	0	\$0	\$0	\$0										
EXT100090	[External Activity] Initial Project Funding Release	Sourikova, Irina	0	01-Feb-17 A			0	0	\$0	\$0	\$0					01-Feb-17 A, ♦					
EXT317000	[External Activity] Design/Safety Reviews Complete, Internal Detector Structural Support Released for Production	Pontieri, Chris	0		19-Jul-19*	319	0	0	\$0	\$0	\$0						19-Jul-19*, ♦				
EXT101010	[External Activity] FY20 Funding Available	Sourikova, Irina	0	01-Oct-19*		417	0	0	\$0	\$0	\$0						01-Oct-19*, ♦				
EXT147100	[External Activity] Procure TPC DAM Felix 2.0 Boards - Contract Award(s)	Hemmick, Tom	0	06-Nov-19*		392	0	0	\$0	\$0	\$0						06-Nov-19*, ♦				
EXT101015	[External Activity] FY21 Funding Available	Sourikova, Irina	0	01-Oct-20*		362	0	0	\$0	\$0	\$0							01-Oct-20*, ♦			
EXT101016	[External Activity] FY22 Funding Available	Sourikova, Irina	0	01-Oct-21*		112	0	0	\$0	\$0	\$0								01-Oct-21*, ♦		
POM028_3.02.3.02	MVTX		741	01-Apr-19	17-Mar-22	0	26695	1266751	\$2,760,452	\$1,569,754	\$4,330,205										
POM028_3.02.3.02.00	Temporary		248	01-Apr-19	26-Mar-20	169	0	0	\$0	\$0	\$0										
POM028_3.02.3.02.00.01	ALICE ITS Key Tasks		0	01-Apr-19	01-Apr-19	255	0	0	\$0	\$0	\$0										
S100000	ALICE ITS RU Production Start	Liu, Ming	0	01-Apr-19*		255	0	0	\$0	\$0	\$0					01-Apr-19*, ♦					
POM028_3.02.3.02.00.02	MVTX Stave Production at CERN		248	01-Apr-19	26-Mar-20	169	0	0	\$0	\$0	\$0										
S100100	Stave Production - Batch 1	Liu, Ming	62	01-Apr-19	26-Jun-19	169	0	0	\$0	\$0	\$0										
S100200	Stave Production - Batch 2	Liu, Ming	62	27-Jun-19	24-Sep-19	169	0	0	\$0	\$0	\$0										
S100300	Stave Production - Batch 3	Liu, Ming	62	25-Sep-19	26-Dec-19	169	0	0	\$0	\$0	\$0										
S100400	Stave Production - Batch 4	Liu, Ming	62	27-Dec-19	26-Mar-20	169	0	0	\$0	\$0	\$0										
POM028_3.02.3.02.00.03	sPHENIX Milestones		0			0	0	0	\$0	\$0	\$0										
POM028_3.02.3.02.01	MVTX Project Management		741	01-Apr-19	17-Mar-22	0	1858	37762	\$592,839	\$48,644	\$641,483										
S100500	Milestone Start MVTX	Liu, Ming	0	01-Apr-19		0	0	0	\$0	\$0	\$0					01-Apr-19, ♦					
S100600	Project Manager	Liu, Ming	741	01-Apr-19	17-Mar-22	0	1238	0	\$395,226	\$0	\$395,226										
S100700	Mechanical Integration Engineer	Liu, Ming	741	01-Apr-19	17-Mar-22	0	310	0	\$98,806	\$0	\$98,806										
S100800	Electronics Integration Engineer	Liu, Ming	741	01-Apr-19	17-Mar-22	0	310	0	\$98,806	\$0	\$98,806										
S100900	Travel FY19	Liu, Ming	128	01-Apr-19	30-Sep-19	112	0	6250	\$0	\$7,813	\$7,813										
S101000	MVTX Construction Start Approval	Liu, Ming	0	01-Apr-19*		0	0	0	\$0	\$0	\$0					01-Apr-19*, ♦					
S101100	Travel FY20	Liu, Ming	251	01-Oct-19	30-Sep-20	112	0	12500	\$0	\$15,938	\$15,938										
S101200	Travel FY21	Liu, Ming	250	01-Oct-20	30-Sep-21	112	0	12500	\$0	\$16,256	\$16,256										
S101300	Travel FY22	Liu, Ming	112	01-Oct-21	17-Mar-22	0	0	6512	\$0	\$8,638	\$8,638										
S101400	MVTX Assembly Complete and Ready for Installation	Liu, Ming	0		17-Mar-22	0	0	0	\$0	\$0	\$0								17-Mar-22, ♦		
POM028_3.02.3.02.02	MVTX Electronics		286	01-Apr-19	19-May-20	363	3863	395448	\$195,007	\$469,960	\$664,967										
POM028_3.02.3.02.02.01	Readout Unit (RU)		193	01-Apr-19	07-Jan-20	453	1137	82428	\$85,282	\$100,435	\$185,717										

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Actual Work

Critical Rem. Work

Remaining Work

Actual LoE

Remaining LoE

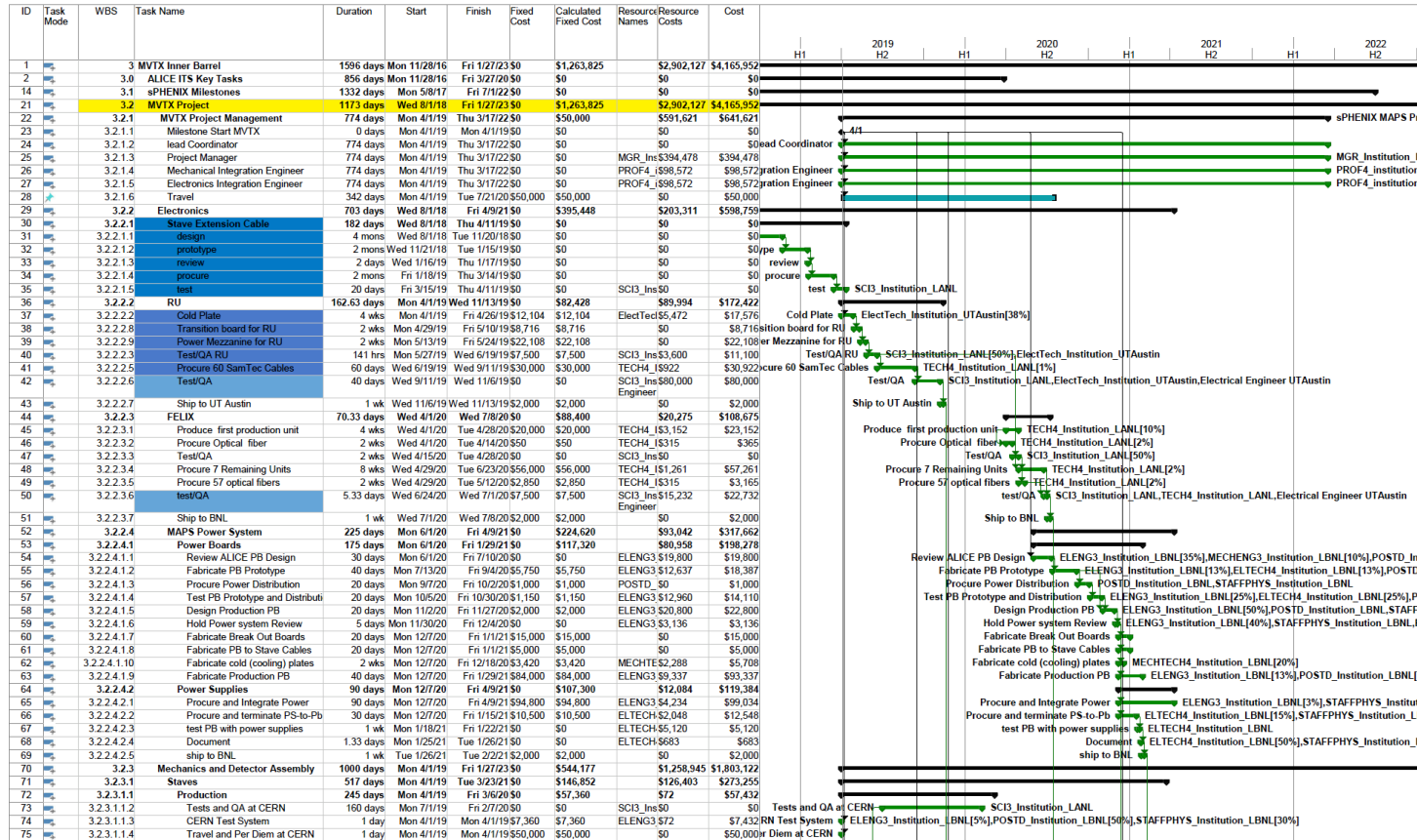
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Milestone

MVTX MS Project 1/4(for estimation) SPHENIX

Thu 4/4/19

MVTX-Barrel-120718-04042019

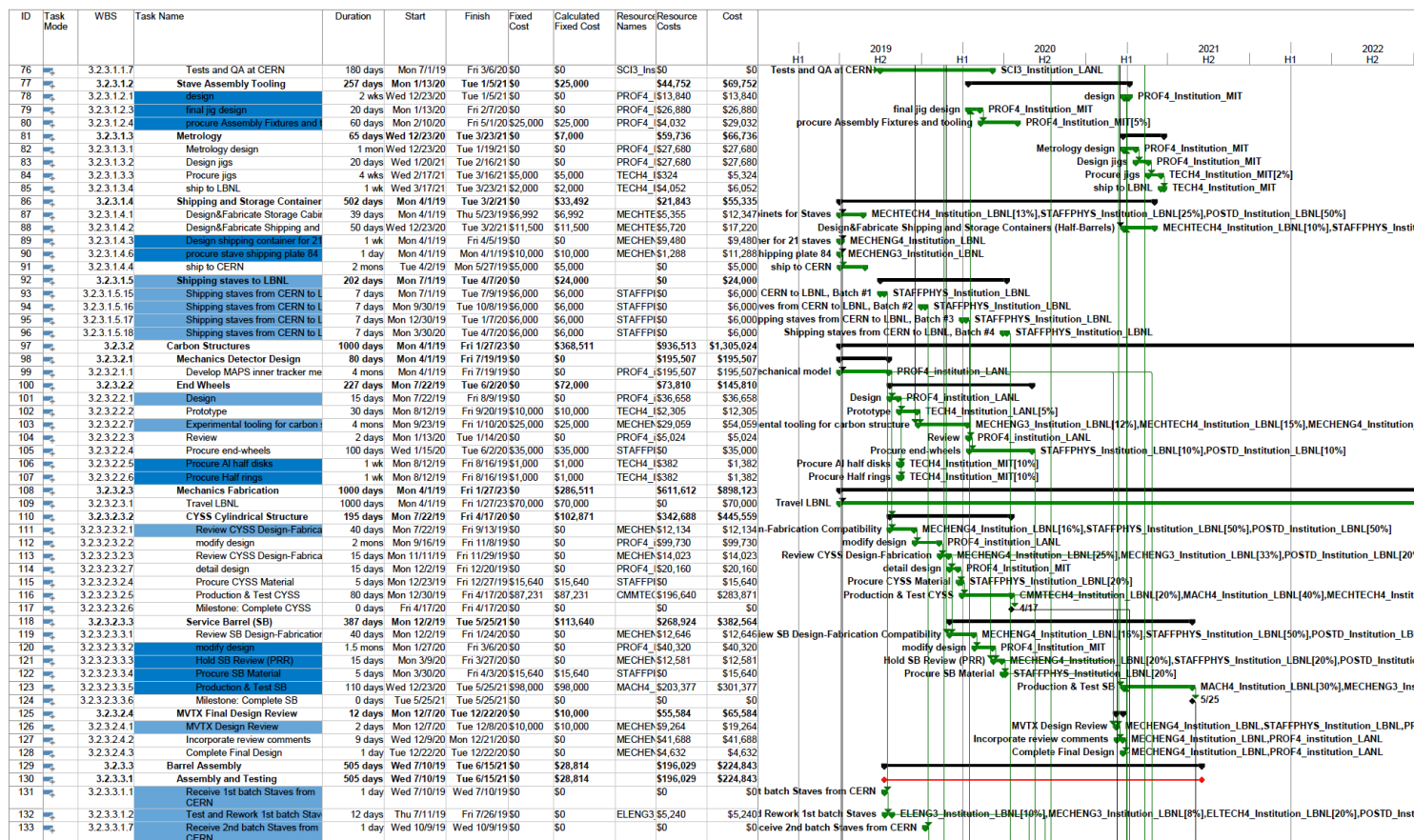


MVTX MS Project 2/4



Thu 4/4/19

MVTX-Barrel-120718-040219

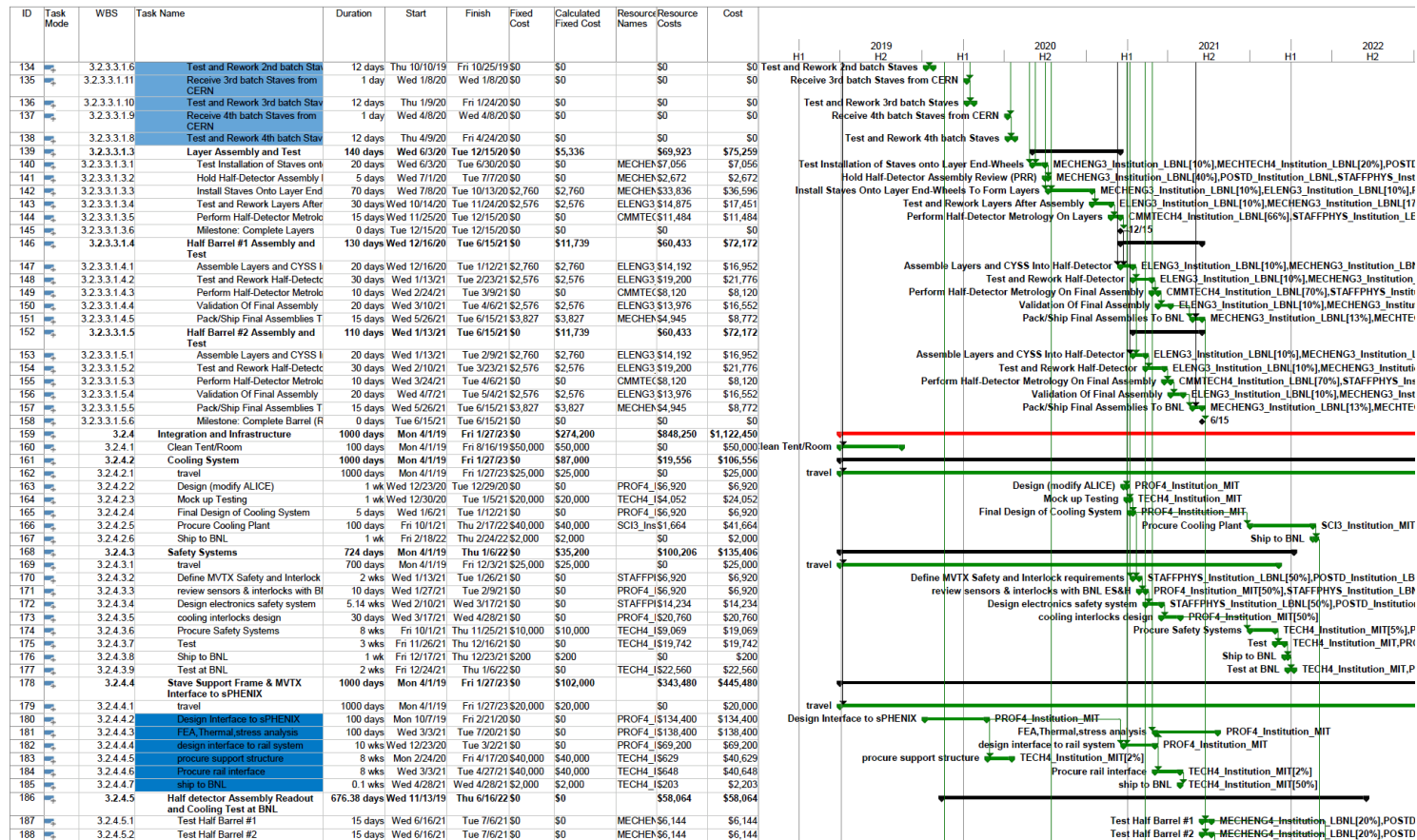


MVTX MS Project 3/4



Thu 4/19

MVTX-Barrel-1207.18-04042019





MVTX-Barrel-120718-04042019

ID	Task Mode	WBS	Task Name	Duration	Start	Finish	Fixed Cost	Calculated Fixed Cost	Resource/Resource Names	Cost	
189		3.2.4.5.3	Assemble & Test Cooling System	20 days	Fri 2/25/22	Thu 3/24/22	\$0	TECH4_Ins\$16,640		\$16,640	
190		3.2.4.5.8	Complete System Test at BNL	3 mons	Fri 3/25/22	Thu 6/16/22	\$0	SC13_Ins\$0		\$0	
191		3.2.4.5.4	test RU at BNL	0.8 wks	Wed 11/13/19	Tue 11/19/19	\$0	SC13_Ins\$12,608		\$12,608	
192		3.2.4.5.5	test FELIX at BNL	0.8 wks	Wed 7/8/20	Tue 7/14/20	\$0	SC13_Ins\$12,608		\$12,608	
193		3.2.4.5.6	PS tests at BNL	0.5 wks	Tue 2/2/21	Thu 2/4/21	\$0	POSTD_Ins\$3,920		\$3,920	
194		3.2.4.6	Installation and Commissioning	387 days	Wed 7/7/21	Thu 12/29/22	\$0	POSTD_Ins\$326,944		\$326,944	
195		3.2.4.6.1	Installation Prep	10 days	Wed 7/7/21	Tue 7/20/21	\$0	Mech_Tech,Phy\$15,520		\$15,520	
196		3.2.4.6.2	Installation Review	1 day	Wed 7/21/21	Wed 7/21/21	\$0	Physicist\$2,320		\$2,320	
197		3.2.4.6.3	Install FELIX	2 days	Thu 7/22/21	Fri 7/23/21	\$0	SC13_Ins\$5,168		\$5,168	
198		3.2.4.6.4	Install Optical fibers	1 wk	Mon 7/26/21	Fri 7/30/21	\$0	TECH4_Ins\$8,120		\$8,120	
199		3.2.4.6.5	Install RU	1 wk	Mon 8/2/21	Fri 8/6/21	\$0	SC13_Ins\$19,320		\$19,320	
200		3.2.4.6.6	Install Samtec Cables	1 wk	Mon 8/9/21	Fri 8/13/21	\$0	TECH4_Ins\$8,120		\$8,120	
201		3.2.4.6.10	Electronics Integration	6 mons	Mon 8/16/21	Fri 1/28/22	\$0	PROF4_Ins\$158,136		\$158,136	
202		3.2.4.6.7	Install Half-Barrel 1	1 mon	Fri 7/1/22	Thu 7/28/22	\$0	MECHTE\$26,320		\$26,320	
203		3.2.4.6.8	Install Half-Barrel 2	1 mon	Fri 7/29/22	Thu 8/25/22	\$0	MECHTE\$26,320		\$26,320	
204		3.2.4.6.9	Commissioning	90 days	Fri 8/26/22	Thu 12/29/22	\$0	Physicist\$57,600		\$57,600	
205		3.2.5	Ready for beam	0 days	Thu 12/29/22	Thu 12/29/22	\$0			\$0	