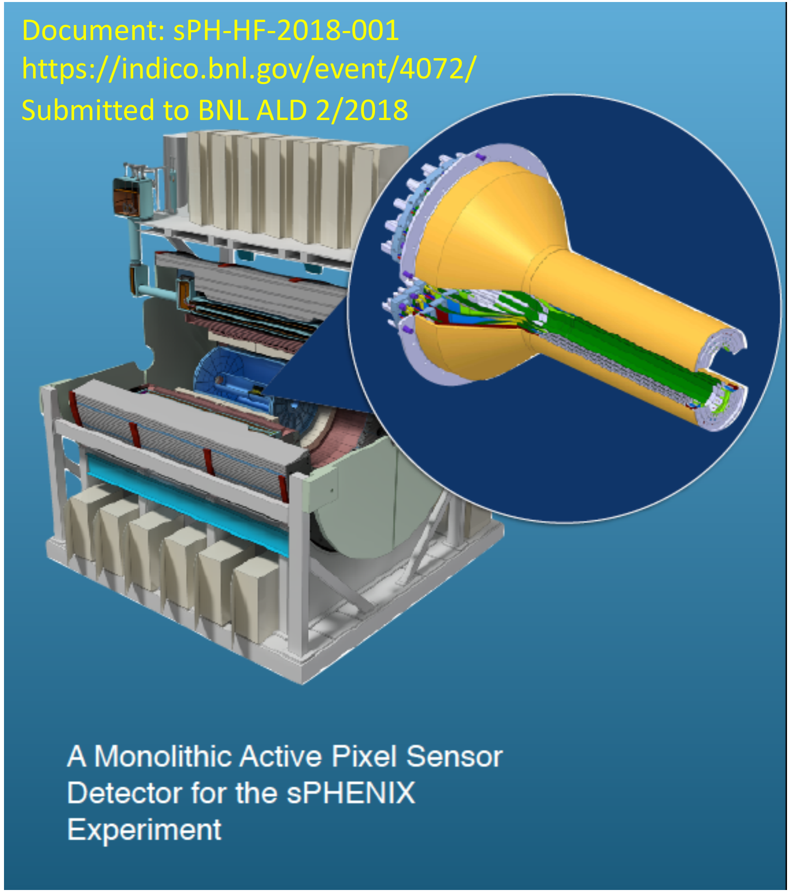
MVTX Overview

Ming Liu, for the MVTX Group
Los Alamos National Laboratory

MVTX BNL Director’s Review
July 19-20, 2018

Outline

- MVTX technology
- MVTX project scope
- Detector design and R&D
- Status and Plan

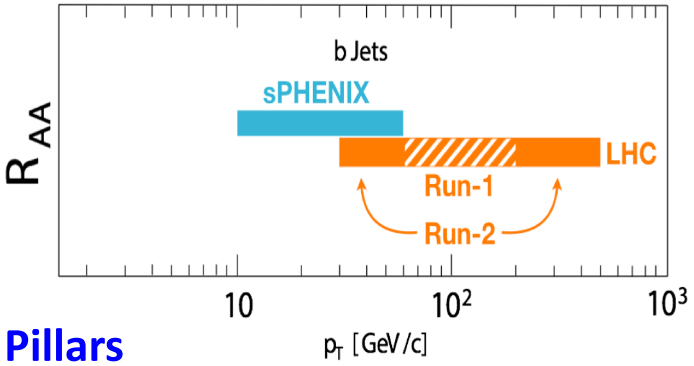


Exciting Science Enabled by MVTX

- sPHENIX is the next flagship heavy ion physics experiment in the US (NSAC LRP2015)
  - Jets
  - Upsilons
  - B-jets and B hadrons
- MVTX will complete QGP heavy flavor physics
  - Precision study of the "inner workings of QGP"(LRP15)
  - Unambiguous determination of key parameters of QGP properties and interactions

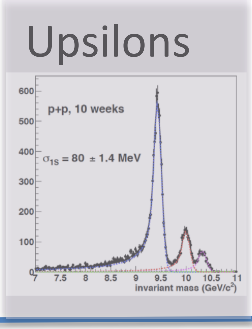
Dave & Gunther

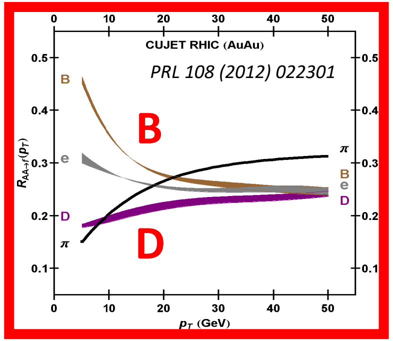
complement & extend current and future RHIC and LHC QGP programs



sPHENIX 3 Physics Pillars

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





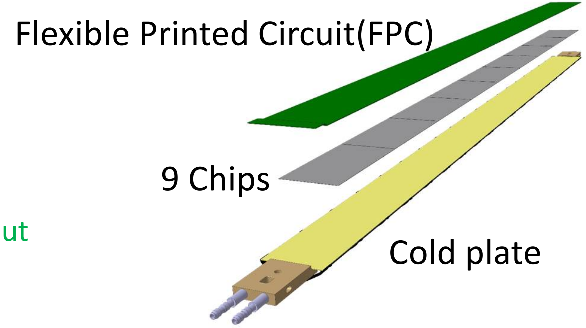
Monolithic Active Pixel Sensors (MAPS)

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

Advantages of ALICE PIxel DEtector (ALPIDE) sensor:

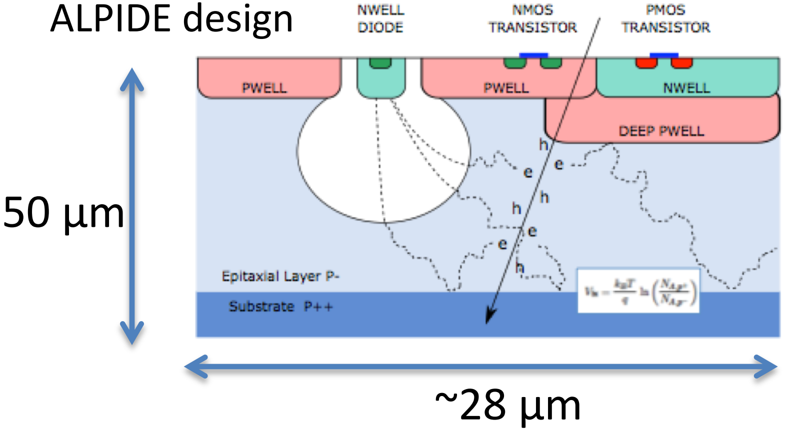
- Very fine pitch (27µm x 29µm), for superb spatial resolution
- High efficiency (>99%) and low noise ($<10^{-6}$), for excellent tracking
- Time resolution, as low as ~5 µs, for less pileup
- Ultra-thin/low mass, 50µm (~0.3% X_0), for less multiple scatterings
- 0.5M channels with on-pixel digitization,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

An ideal detector for QGP physics!



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

ALPIDE design

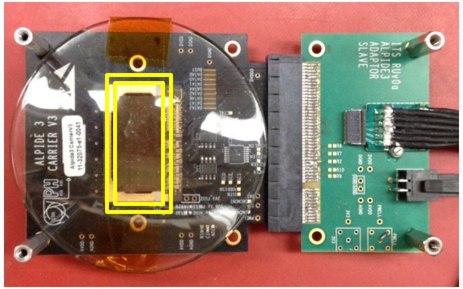


Tower Jazz 0.18 µm CMOS

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

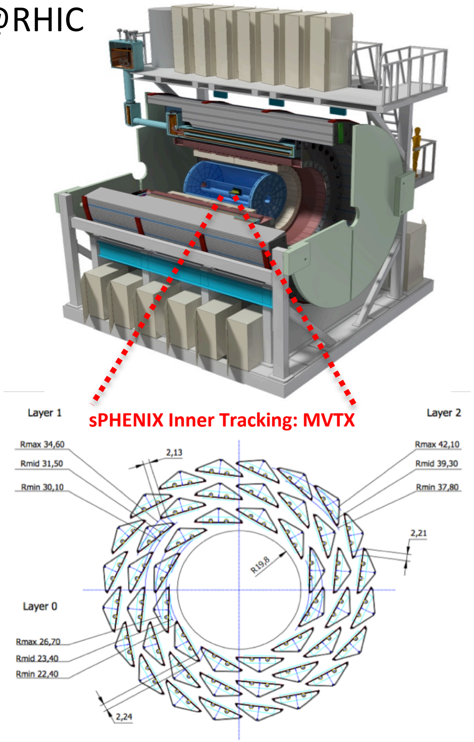
substrate: $N_A \sim 10^{18}$
epitaxial layer: $N_A \sim 10^{13}$
deep p-well: $N_A \sim 10^{16}$

ALPIDE sensor:
1.5cm x 3.0cm, 0.5M channels

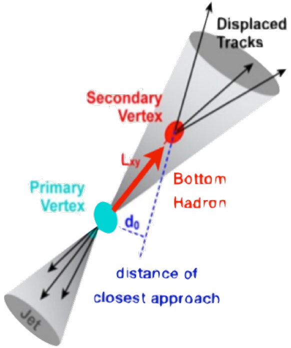


MVTX: MAPS-based VerTeX Detector

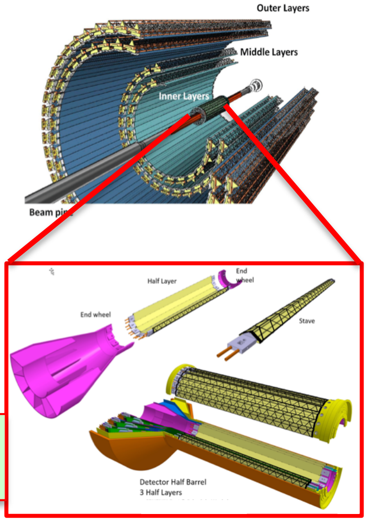
sPHENIX@RHIC
(2023+)



Key integration tasks:
- Readout
- Mechanics



ALICE ITS Upgrade @CERN;
Inner Tracker System (2021+)



"Adopt" ALICE ITS/IB:
- Minimum risk
- Maximum physics

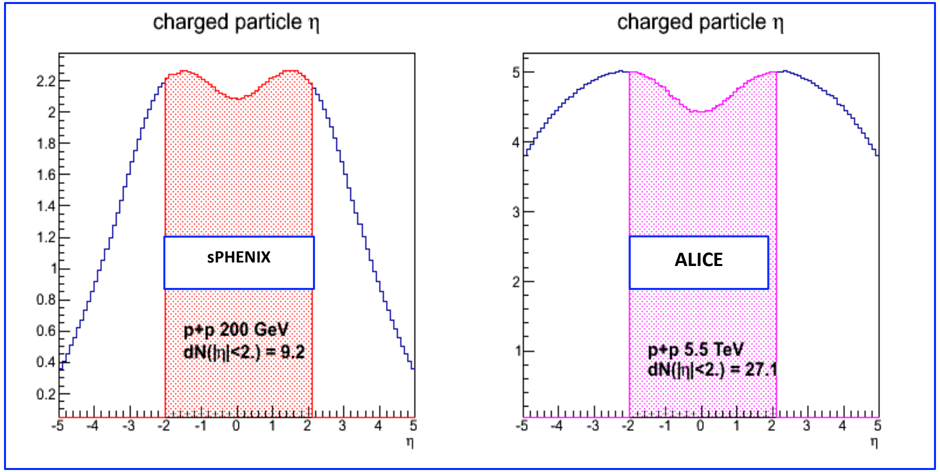
Leveraging on extensive R&D and design work by ALICE

sPHENIX vs ALICE

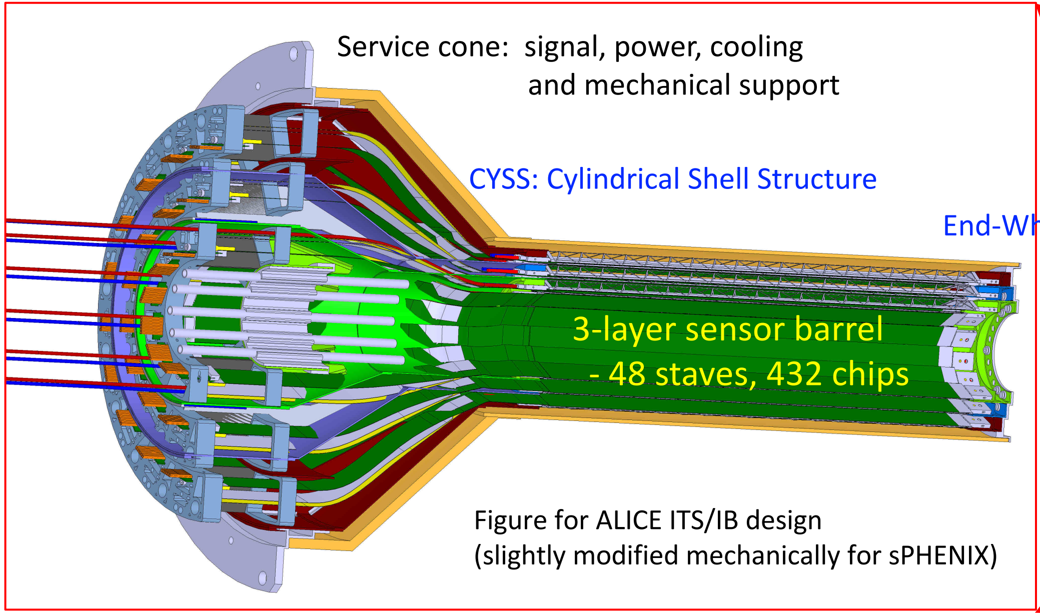
	ALICE (Run3)	sPHENIX (Max)	Ratio of data rates sPHENX/ALICE
Pb+Pb / Au+Au	50kHz	200 kHz	0.3
p+p	200kHz	13 MHz	(1.6)
Trigger/Readout	50 kHz/(Continues)	15 kHz	-

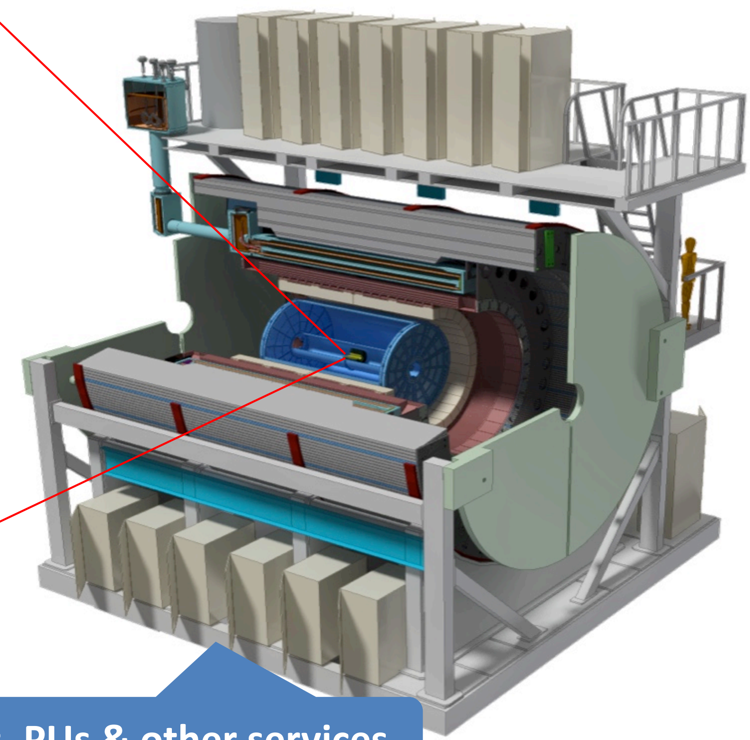
- MB Event track multiplicity dN/dη
  - sPHENIX = 1/3 ALICE (pp)
  - sPHENIX = 1/5 ALICE (AA)

sPHENIX triggered data rate fits well within ALICE readout hardware specs;



MVTX Detector





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

Scope of the MVTX Project

- MAPS Staves & Electronics
  - Readout Integration R&D (LANL LDRD)
    - Frontend: ALICE/ITS, RU
    - Backend: ATLAS FELIX
    - Reprogram RU & FELIX for sPHENIX
  - Production:
    - **84 ALICE/ITS-IB staves from CERN**
      - Acceptance test @LBNL 48+spares(36)
    - **58 ALICE/ITS-RU from CERN**
      - Acceptance test @UT-Austin, 48+spares(10)
    - Reproduce 8 ATLAS/FELIX
      - Acceptance @LANL
    - Final assembly and test in US
      - LBNL and BNL
  - Ancillary systems, “adopt” ALICE system

Alex Tkatchev & Sho Uemura

Leo Greiner

Jo Schambach

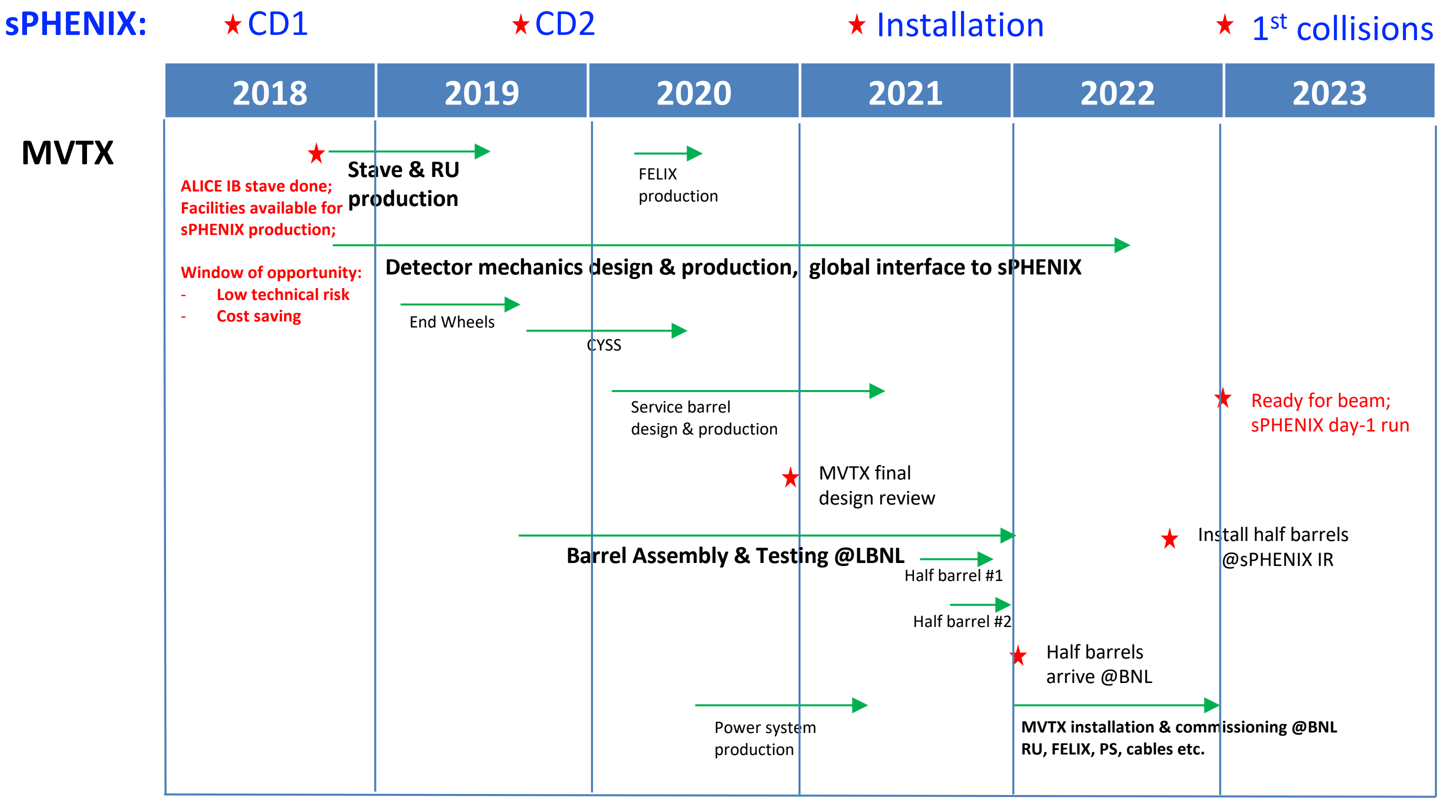
- Mechanics & Cooling
  - Some changes to ALICE/ITS inner tracker mechanical structures,
    - End Wheels
    - Cylindrical structure shells
    - Detector half barrels
    - Detector and Service half barrels
  - Mechanical Integration,
    - Conceptual design by LANL LDRD
    - Prototype by sPHENIX R&D, MIT/LANL
    - Design integration frames
    - Carbon frames etc., LBNL
    - Installation tooling etc.
  - Adopt ALICE cooling plant design
    - Minor modification to fit sPHENIX
    - Much smaller heat load than ALICE ITS

Walt Sondheim

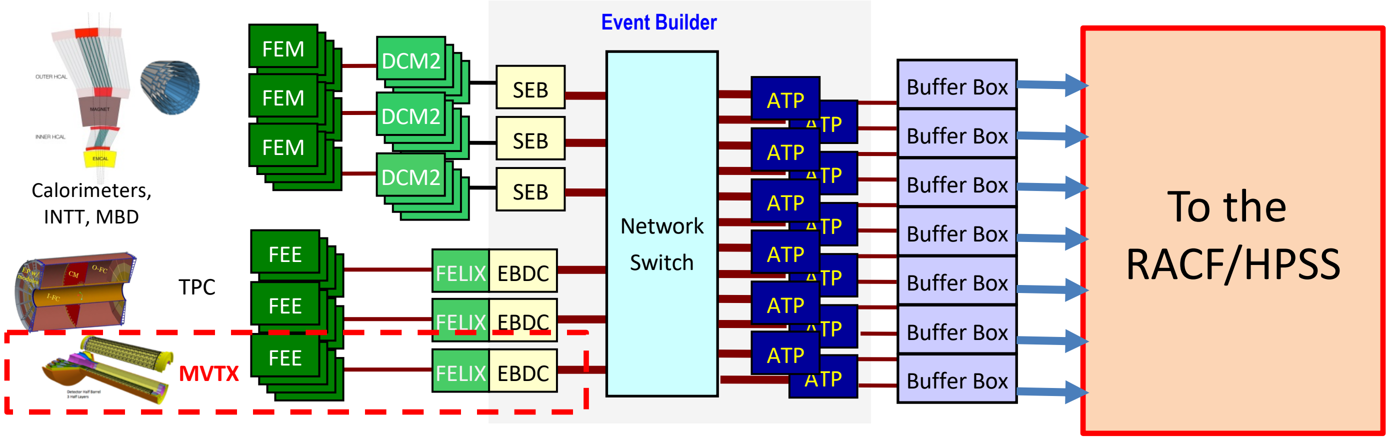
Walt Sondheim & Dan Cacace

- Early R&D by LANL LDRD, $5M, FY17-19, readout, mechanical design and physics
- Established LANL-ALICE MoU in 12/2016 for joint R&D for MVTX

Schedules and Milestones



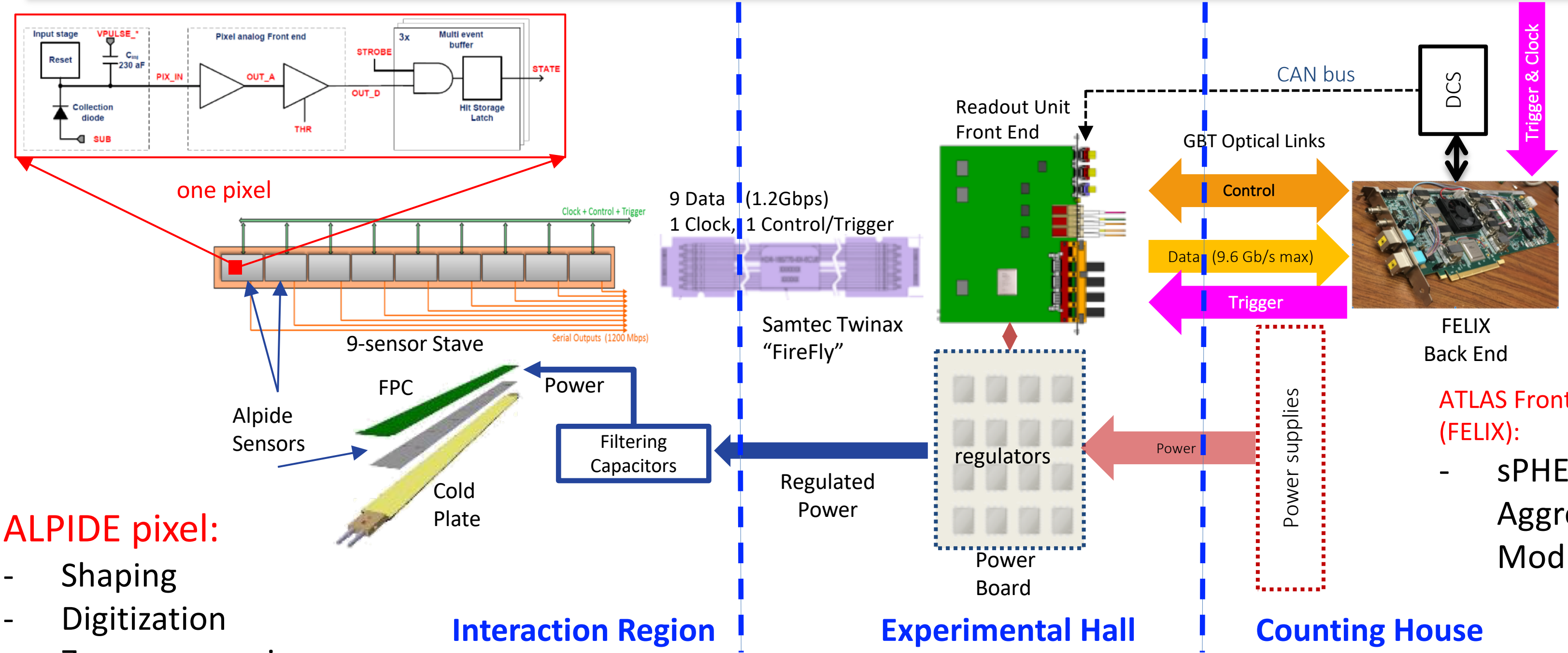
sPHENIX DAQ Architecture



- 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 Readout, Power and Controls

Alex,Sho, Jo, Leo #1,2,3



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

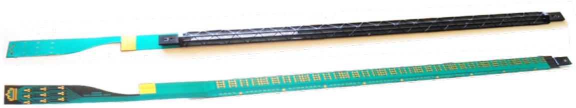
Sensor-Stave (9 ALPIDE chips) | **Front End**-Readout Unit | **Back End**-FELIX/DAM

MVTX Sensors and Electronics

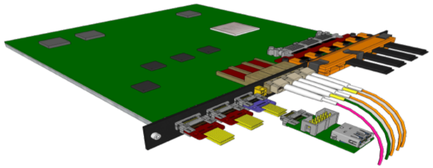
Alex, Sho, Leo, Jo

Major hardware:

- 48 ALICE ALPIDE Staves + Interface Cables
- 48 Front End Electronics (ALICE RUv2)
- 6 Back End Electronics (ATLAS FELIX v2)
- 6 EBDC Linux servers
- 24 Power Boards + CEAN Supplies + Cables
- 48 Stave to RU cables
- 144 data fiber optic cables (3 fibers x 48 FEE)



ALICE ITS/IB stave



ALICE ITS RU

Stave production spares: 75%

Electronics production spares: 20%

Projected Radiation Level after 5-year Runs

http://www.rhichome.bnl.gov/RHIC/Runs/RhicProjections.pdf

sPH-TRG-2018-001

Leo #1

Year	Species	Energy [GeV]	Phys. Wks	Rec. Lum.	Samp. Lum.	Samp. Lum. All-Z
Year-1	Au+Au	200	16.0	7 nb^{-1}	8.7 nb^{-1}	34 nb^{-1}
Year-2	p+p	200	11.5	—	48 pb^{-1}	267 pb^{-1}
Year-2	p+Au	200	11.5	—	0.33 pb^{-1}	1.46 pb^{-1}
Year-3	Au+Au	200	23.5	14 nb^{-1}	26 nb^{-1}	88 nb^{-1}
Year-4	p+p	200	23.5	—	149 pb^{-1}	783 pb^{-1}
Year-5	Au+Au	200	23.5	14 nb^{-1}	48 nb^{-1}	92 nb^{-1}

Projected sPHENIX integrated luminosities after 5-year operation

- AuAu: Lum. = 214 nb^{-1}
- pp+pAu: Lum. = 1340 pb^{-1}

PHENIX study
arXiv: 0710.2676 [nucl-ex]

Projected sPHENIX MVTX L0 fluence: TID = 1060krad

NIEL = $6x10^{12}$ N_{eq}/cm^2

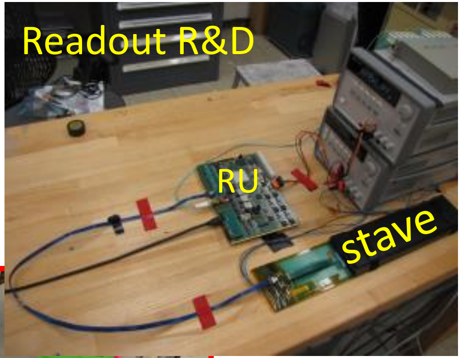
Outer layers:

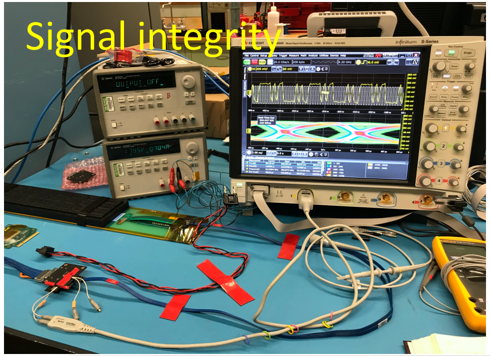
L1 = 0.6 x L0; L2 = 0.4 x L0

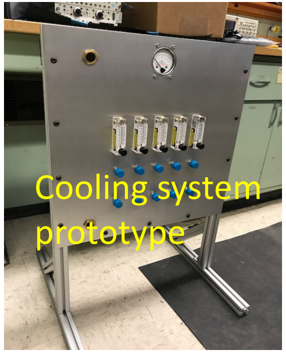
Sensors tested to full MVTX NIEL and ~1/2 TID @ALICE

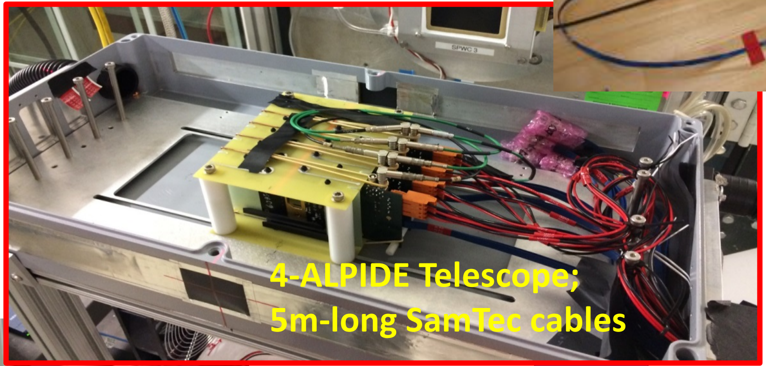
LANL LDRD Activity Highlights

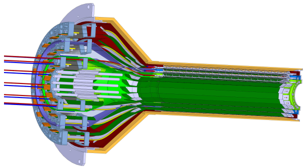
- MAPS evaluation
- Readout integration
- 4-sensor telescope
- Test beam at Fermilab
- Mechanical & cooling

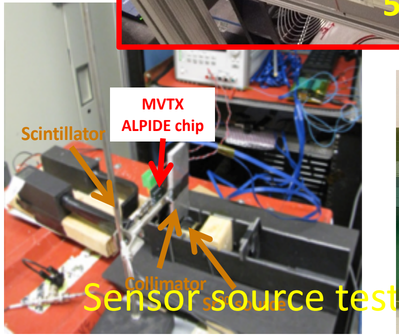


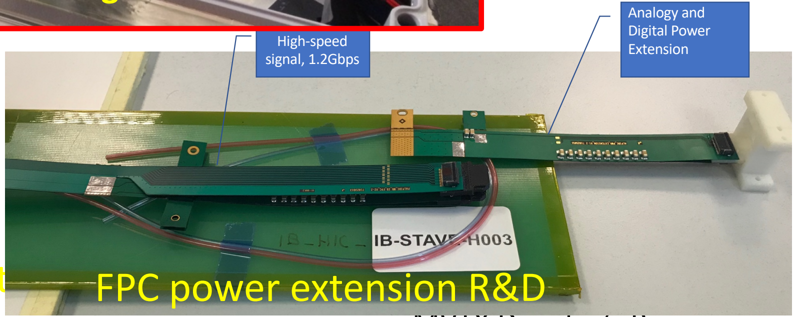




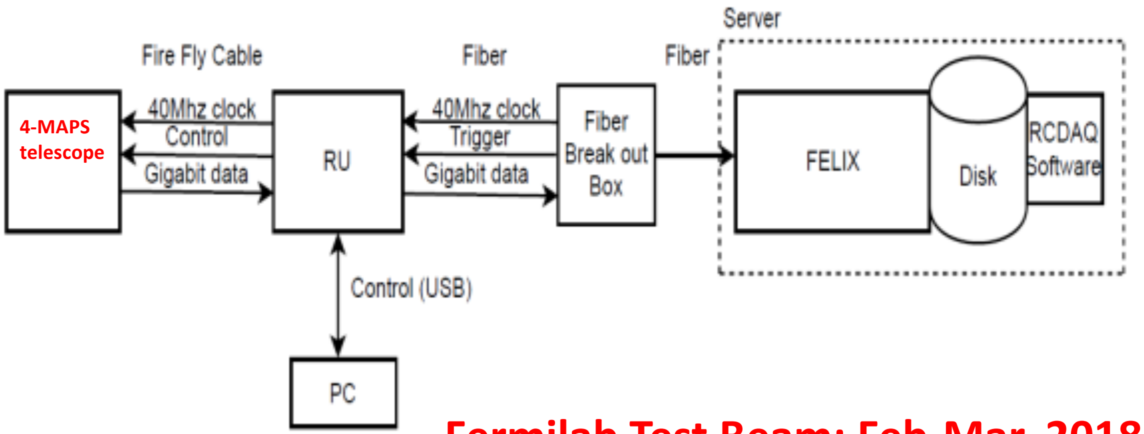


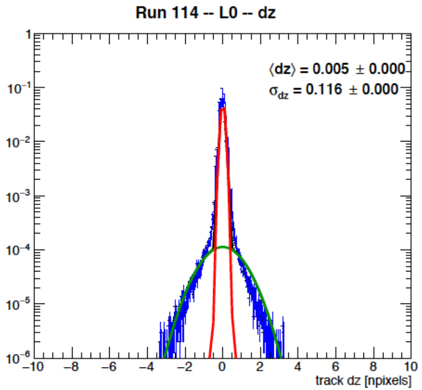






MVTX Full Readout Chain Demonstrated

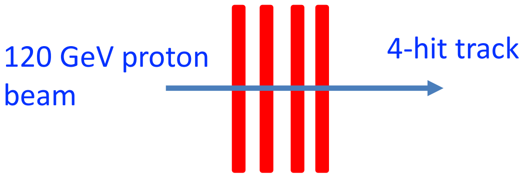




Alex & Sho #1,2,3

Tracking spatial resolution achieved: <5 um

Fermilab Test Beam: Feb-Mar, 2018



4-MAPS telescope

Stave and RU Production QA Plan

Leo & Jo
#4,5,6,7,8

Staves

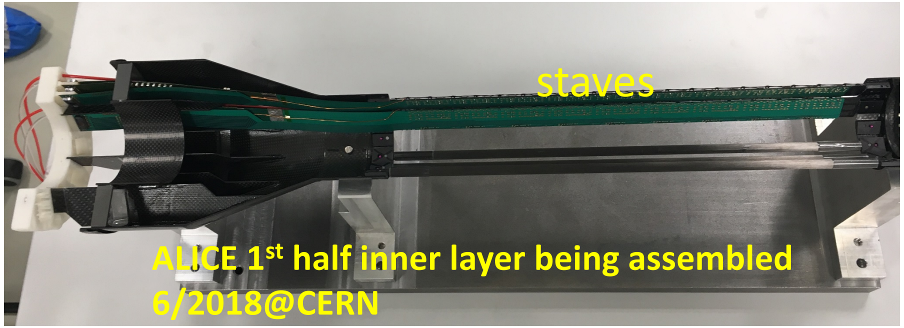
- Purchase 84 staves from ALICE/CERN
  - 48 + 28(spares for 2 inner layers) + 8 spares
  - Production following the completion of ALICE ITS/IB
  - Starting ~Oct. 2018, will last 6-12 months
  - Fully tested at CERN before shipping to US
    - All Gold/Silver staves (same as ALICE IB)
    - A LANL postdoc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

Readout Units

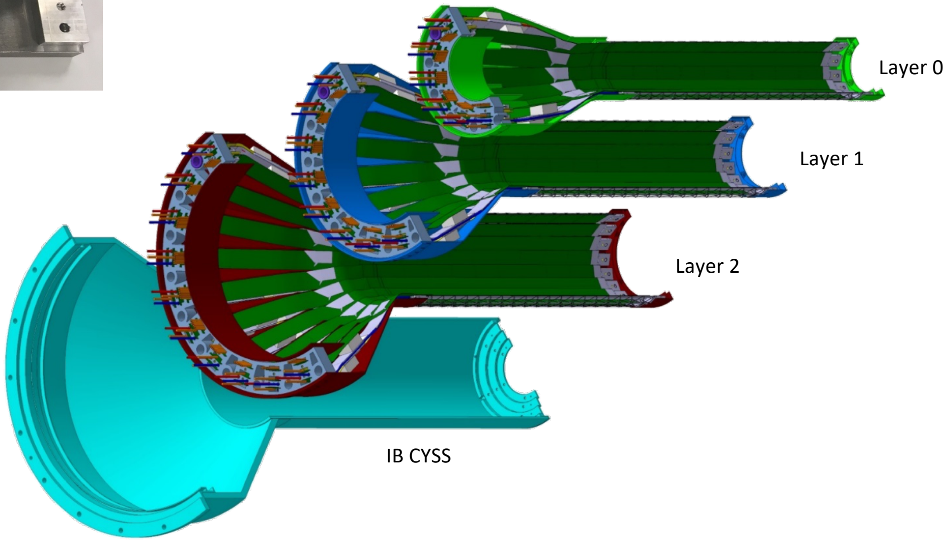
- Purchase 58 RUs from ALICE/CERN
  - 48 + 10 spares(20%)
  - To be part of ALICE production
    - Cost saving
    - Minimize technical risks
  - Initial test at CERN
- Acceptance QA at UT-Austin
  - Full test
  - LANL as the 2nd test site

Detector Assembly Plan at LBNL

Leo's talk
#4,5,6,7,8



Precision positioning and installation of staves on end-wheels

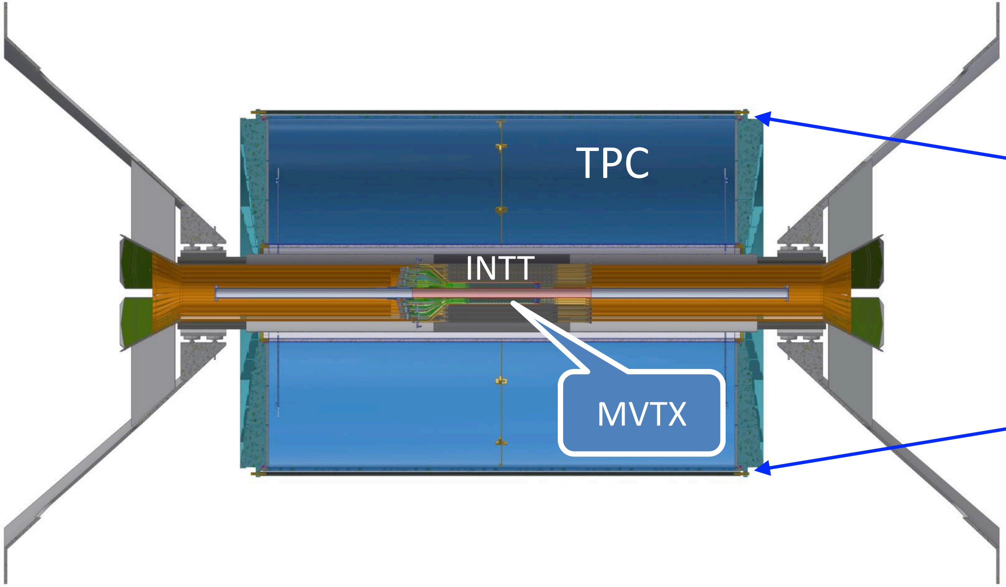


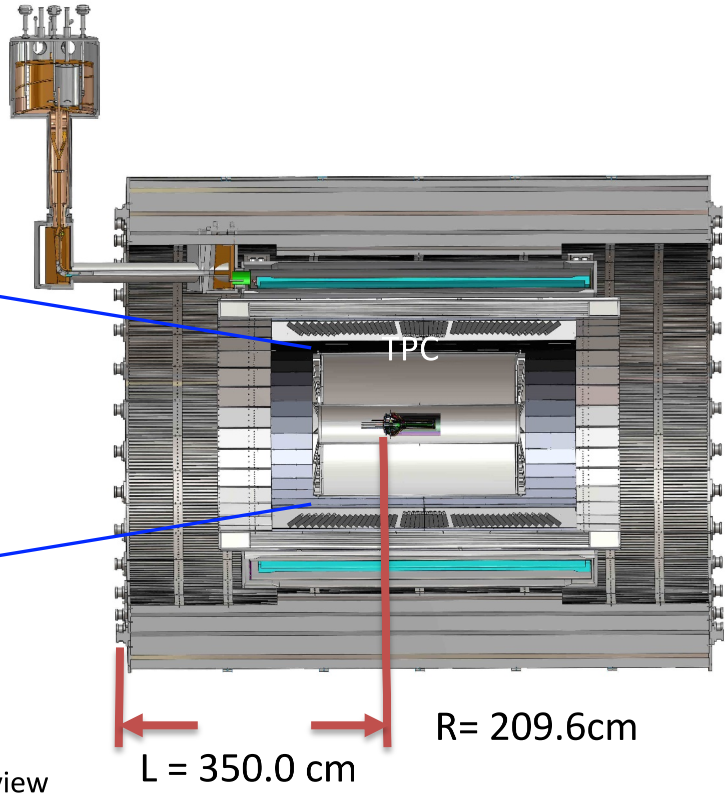
- Follow ALICE IB assembly procedures to build half-detectors for MVTX
- QA records in DB, travelers
- Modified jigs for MVTX

Mechanical Integration

Walt & Dan
#10

- MVTX, INTT and TPC/HCal
  - MVTX/INTT detector designs modified
  - Global interface being developed



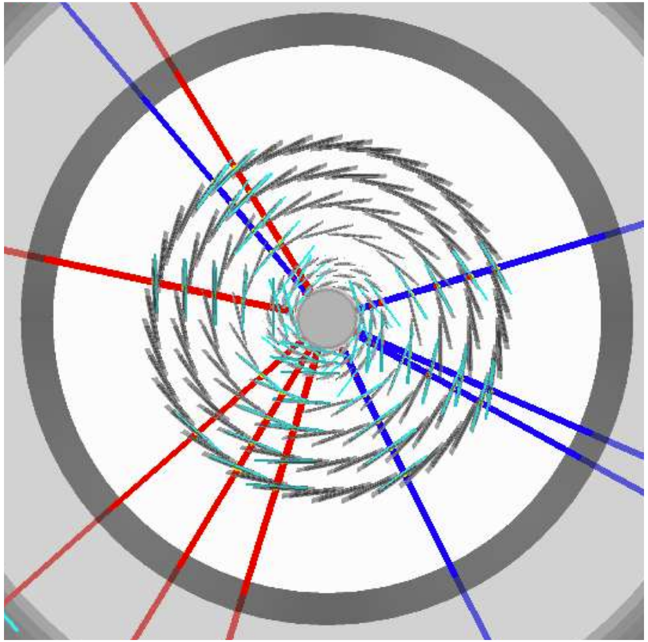


Simulations for Optimization

Tony & Rachid
#9, 10

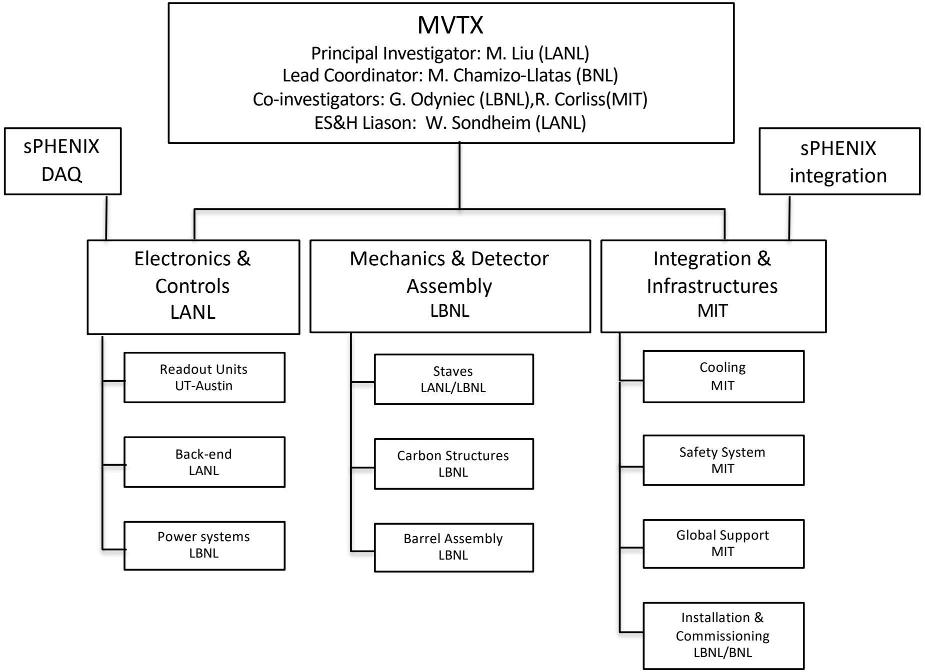
- Task force formed
  - Goals and deadline defined
  - Evaluate tracking with different INTT layers & geometry

- Complementary roles in global tracking:
  - MVTX:
    - Precision DCA and vertexing
  - INTT:
    - Matching in-time hits of MVTX and TPC
    - Important for p+p and p+A, pileups



sPHENIX MVTX Group: Institution Roles

- Growing number of institutions
  - Major institutions lead key tasks



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

Summary

- Compelling science established

  Dave & Gunther

- Demonstrated full readout and control chain in sPHENIX framework
  - Charge #1,2,3

  Alex & Sho

- Demonstrated detector performance with test beam data
  - Charge #1,2,3

  Alex & Sho

- QA plan developed for RUs and Staves
  - Charge #4,5,6,7,8

  Leo & Jo

- 3D design of mechanical integration
  - Charge #10

  Walt & Dan

- Simulation to optimize INTT geometry
  - Charge #9, 10

  Rachid & Tony

Associate Laboratory Director for Nuclear and Particle Physics

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for the U.S. Department of Energy

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Review of the sPHENIX pixel vertex detector, MVTX

July 19-20, 2018
Charge to the review committee

The purpose of the review is to evaluate the maturity of the design of the sPHENIX pixel detector, MVTX, and the readiness for procurement of the Staves and Readout Units.

In carrying out its charge, the review committee is requested to evaluate the following specific items:

1. Does the current design demonstrate that the MVTX Staves and Readout Units will be compliant with its specifications?
2. Can the data from MVTX staves be extracted, readout and integrated into sPHENIX Data Acquisition System?
3. Are the electrical interfaces of the Staves and Readout Units to other sPHENIX components at a proper level of understanding?
4. Has the responsibility for fabrication, tests and acceptance for the Staves and Readout Units been defined?
5. Has a QA plan and acceptance tests for the Staves and Readout Units been clearly defined and documented?
6. Has the inspection/test records archive plan been clearly defined and is the information easily accessible?
7. Is the design of the Staves and Readout Units final?
8. Are the Staves and Readout Units ready for procurement?

The review committee is also requested to evaluate the following specific items concerning the maturity of the design and its integration within sPHENIX:

9. Status of the simulation to optimize the MVTX and INTT for tracking in sPHENIX and timescale for its completion
10. Status of the mechanical integration between the MVTX, INTT and other sPHENIX components and timescale for a final design

Reviewers may additionally, at their discretion, comment on any other notable issues and/or concerns which they identify.

A report from the committee is expected to be submitted to me by July 27, 2018.

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

Berndt Mueller
Associate Laboratory Director for Nuclear and Particle Physics
Brookhaven National Laboratory