MVTX Overview

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For the sPHENIX MVTX Upgrade Group

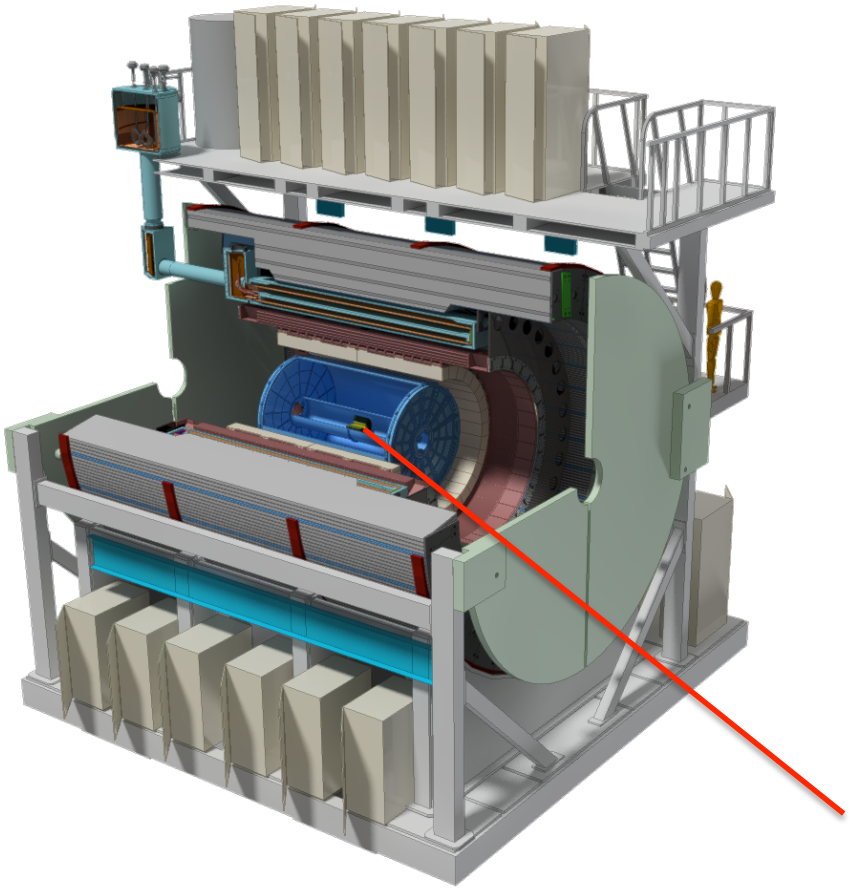
sPHENIX BNL Director's Review
August 2-4, 2017

Monolithic-Active-Pixel-Sensor (MAPS) based Vertex Detector for sPHENIX

A separate upgrade project for the baseline sPHENIX experiment, with

1) Compelling Science
2) Feasible Cost & Schedule

MVTX BNL Director's Review: July 10-11, 2017



WBS	sPHENIX MIE Project Elements
1.1	Project Management
1.2	Time Projection Chamber
1.3	Electromagnetic Calorimeter
1.4	Hadron Calorimeter
1.5	Calorimeter Electronics
1.6	DAQ-Trigger
1.7	Minimum Bias Trigger Detector

WBS	Infrastructure & Facility Upgrade
1.8	SC-Magnet
1.9	Infrastructure
1.10	Installation-Integration

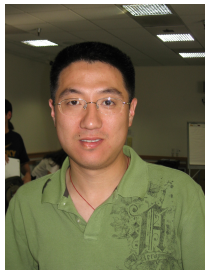
Parallel Activities

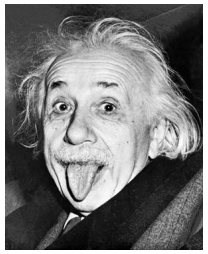
- MAPS-based Vertex Detector (MVTX)
- Intermediate Silicon Strip Tracker (INTT)

Summary: July 2017 MVTX BNL Directors Review

https://indico.bnl.gov/conferenceDisplay.py?confId=3270

- MVTX Overview – Ming
- Exciting science - Xin
  - New B-physics program @RHIC
- Early ALICE & ATLAS R&D investment
  - Reduce technical risk and R&D cost
- LANL LDRD critical - Cesar
  - mitigate risks and minimize contingency
- No high risk R&D – Mark, Giacomo, Walt
  - Readout
  - Mechanics
  - MVTX integration
- Ready for sPHENIX Day-1 – Ed, Dave
  - sPHENIX integration
  - Cost & Schedule







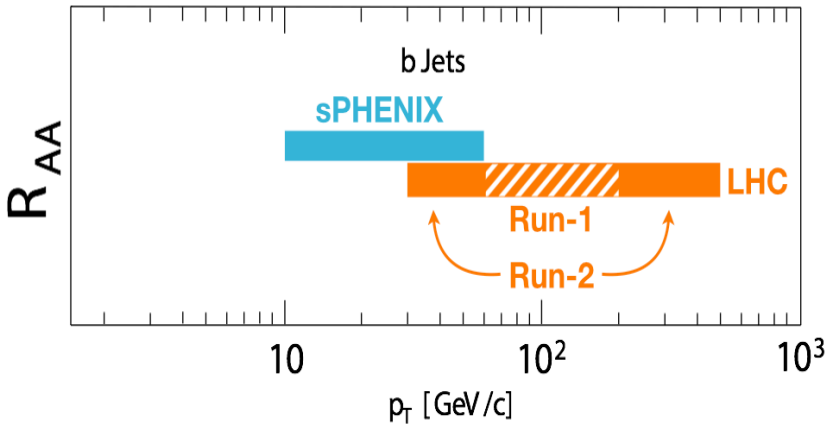

Outline

- Science of MVTX detector
- Scope of MVTX project
  - Readout
  - Integration
  - Cost & schedule
- Organization & plan

Exciting Science

- 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" (NP LRP15)
  - Unambiguous determination of key parameters of QGP properties and interactions

complement & extend current and future RHIC and LHC QGP programs

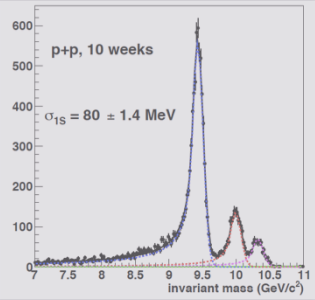


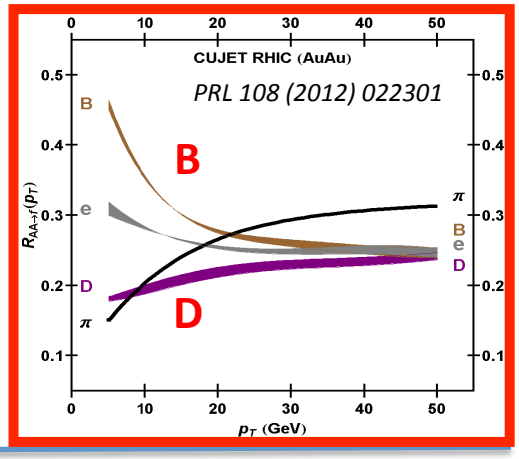
sPHENIX 3 Physics Pillars

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

Jets

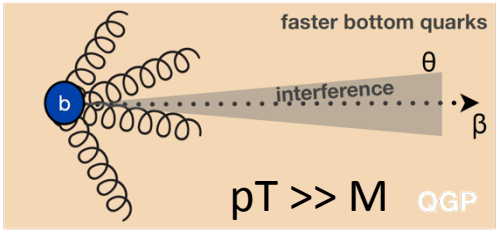
Upsilons

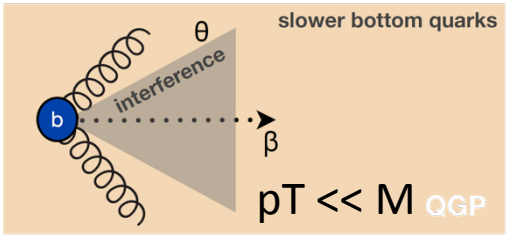




MVTX – Bring sPHENIX to a New Horizon

- Unambiguously determine quark energy loss mechanisms, particularly over the interesting transition region, pT ~ M
  - Radiative dE/dX
  - Collisional dE/dX
  - Other effects





Expectations @sPHENIX

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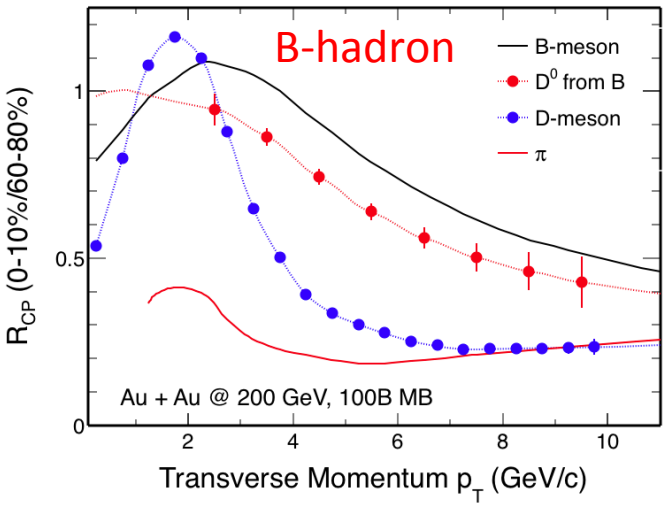

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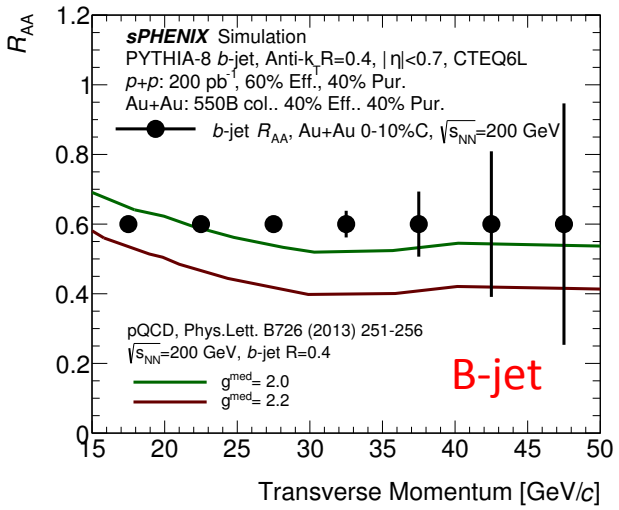
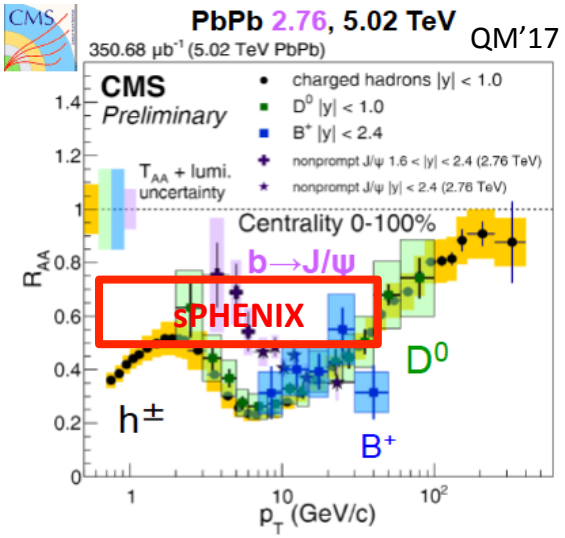
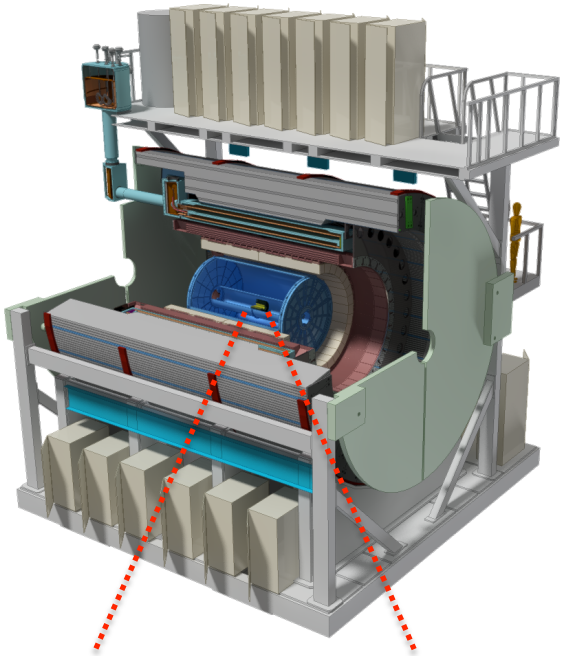


Learned @CERN



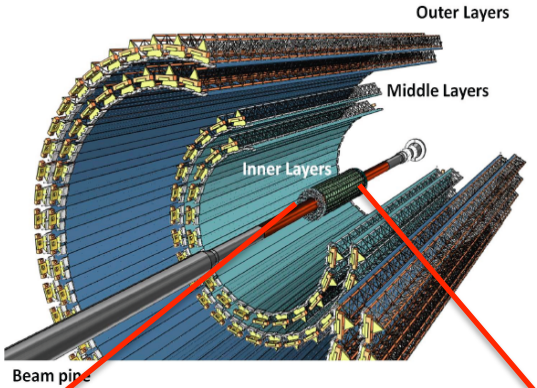
Our Approach: MVTX



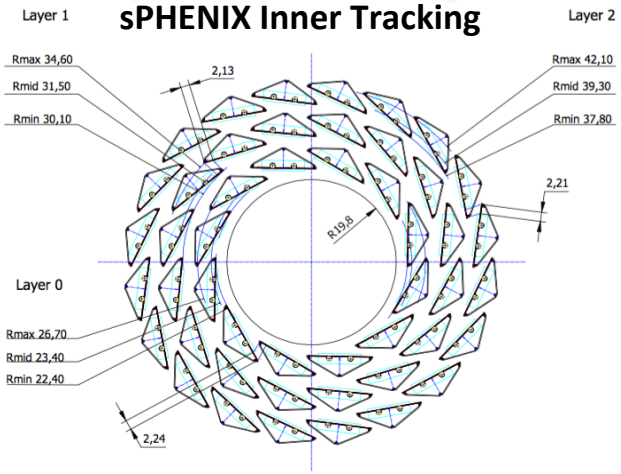
Major challenges:
- Readout
- Mechanics

J. Phys. G 41 (2014) 087002

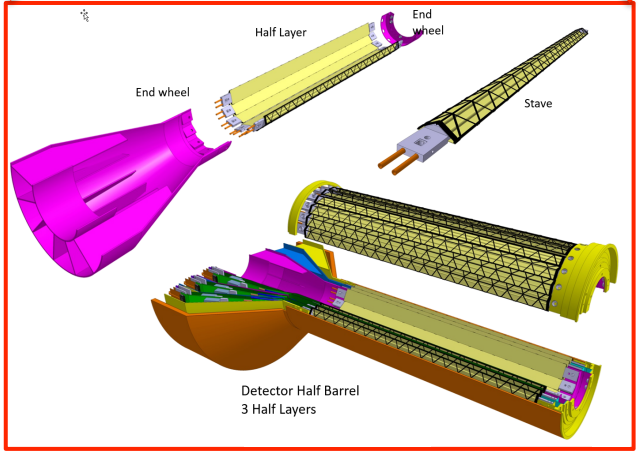
ALICE ITS Upgrade:
Inner Barrel Tracker



R = 23/32/39 mm
Z = 271 mm



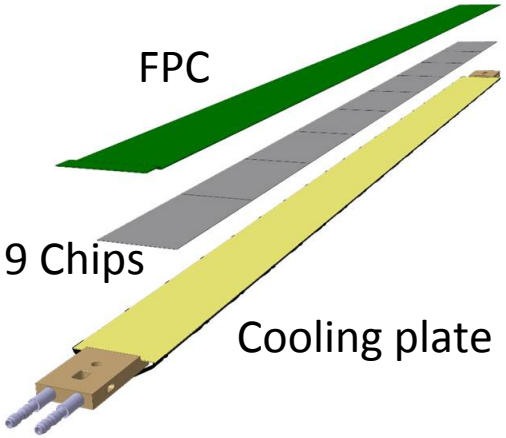
ADAPT ITS/IB:
- MIN. RISKS
- MAX. PHYS.



Monolithic-Active-Pixel-Sensors (MAPS)

The next Generation State of the Art Pixel Tracker

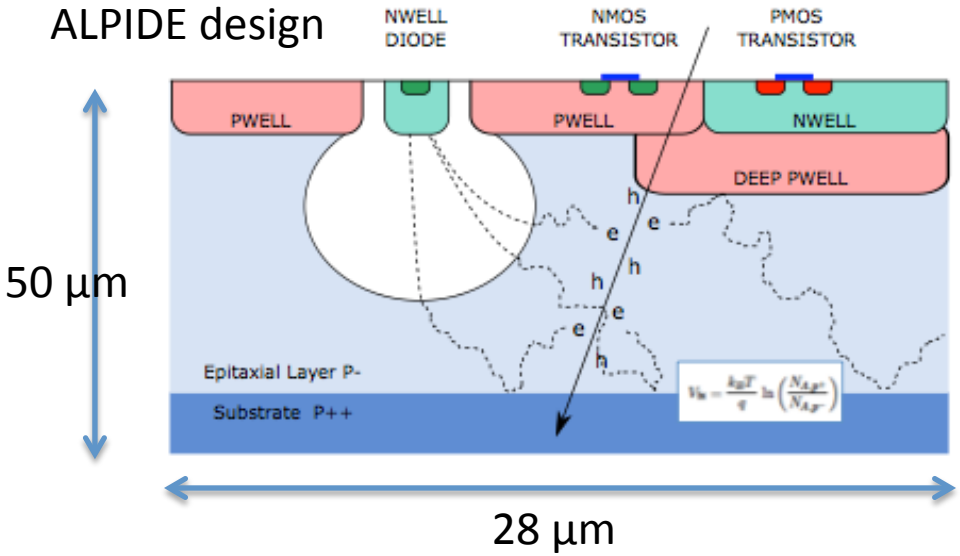
- Advantages of ALICE MAPS/ALPIDE:
  - Very fine pitch (28x28 µm)
  - High efficiency (>99%) and low noise (<10^{-6})
  - Time resolution, as high as ~5 µs
  - Ultra-thin/low mass, 50µm (~0.3% X_0)
  - On-pixel digitization, low power dissipation



A 9-chip MAPS stave, 1.5 x 27cm^2

An ideal detector for QGP physics!

ALPIDE design



Tower Jazz 0.18 µm CMOS

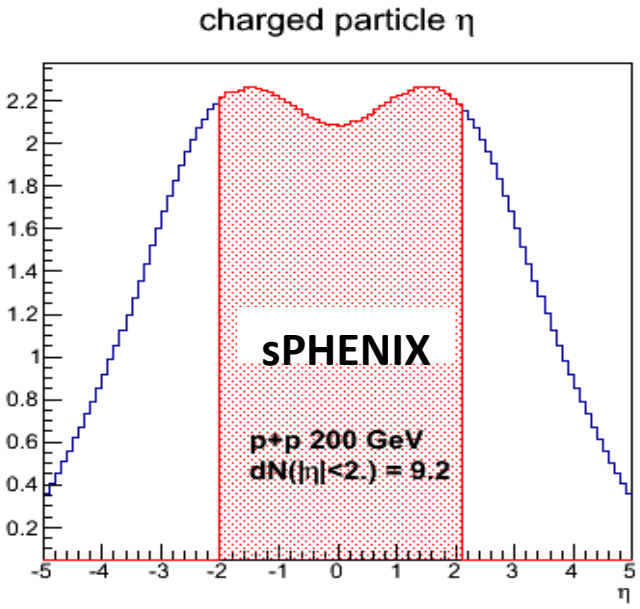
- feature size 180 nm
- metal layers 6
- gate oxide 3nm

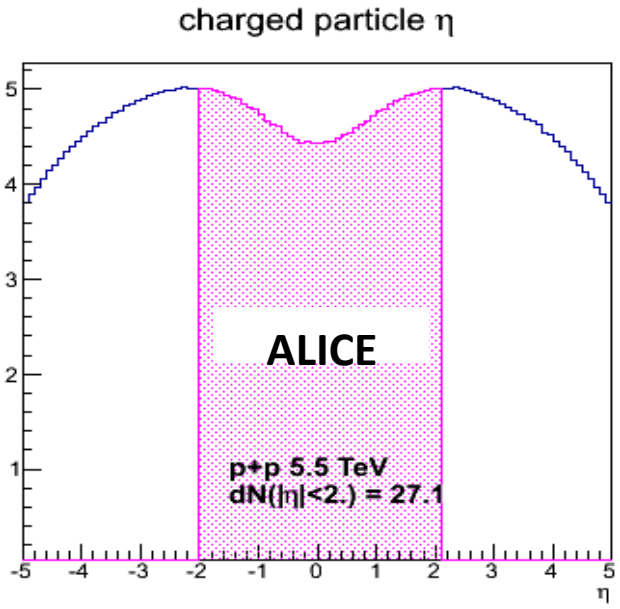
substrate: $N_A \sim 10^{18}$
epitaxial layer: $N_A \sim 10^{13}$
deep p-well: $N_A \sim 10^{16}$

sPHENIX MVTX vs ALICE ITS/IB

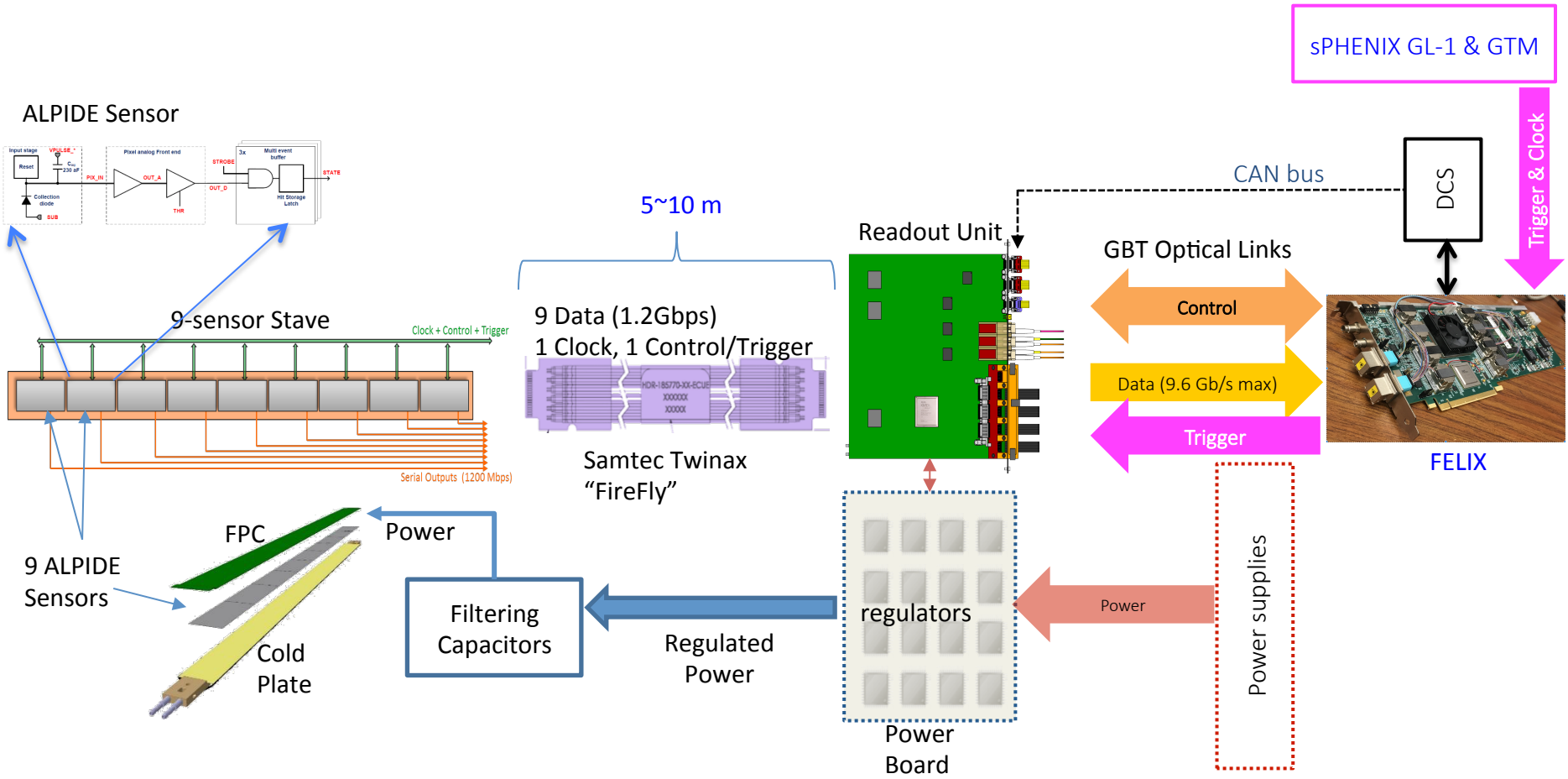
	ALICE (Run3)	sPHENIX (Max Collis.)
Pb+Pb / Au+Au	100 kHz (50kHz)	200 kHz
p+p	400 kHz (200kHz)	13 MHz
Trigger/Readout	>50 kHz	15 kHz

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





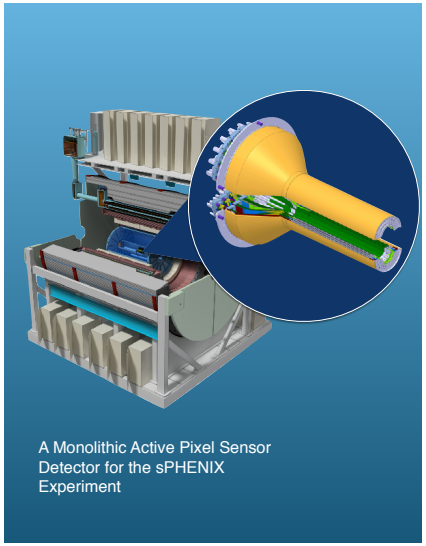
MVTX Readout and Control System



LANL, UT-Austin, LBNL, BNL, ALICE/ITS …

MVTX Pre-proposal Submitted!

- Pre-proposal submitted to DOE, 2/2017
  - Follow-up discussions with DOE and BNL managers
  - Weekly proj. leaders' meeting, BNL/LANL/LBNL/MIT
- Plan to update proposal to DOE, late 2017
  - Expanded science + Cost & Schedule
  - Assumed funding starts in FY18
  - BNL Director's Review, 7/10-11, 2017
- A growing collaboration
  - 15+ institutions from US and abroad



- Adapt ALICE ITS Upgrade Inner Barrel 3-layer MAPS detector
  - Mini. risk, Max. Physics

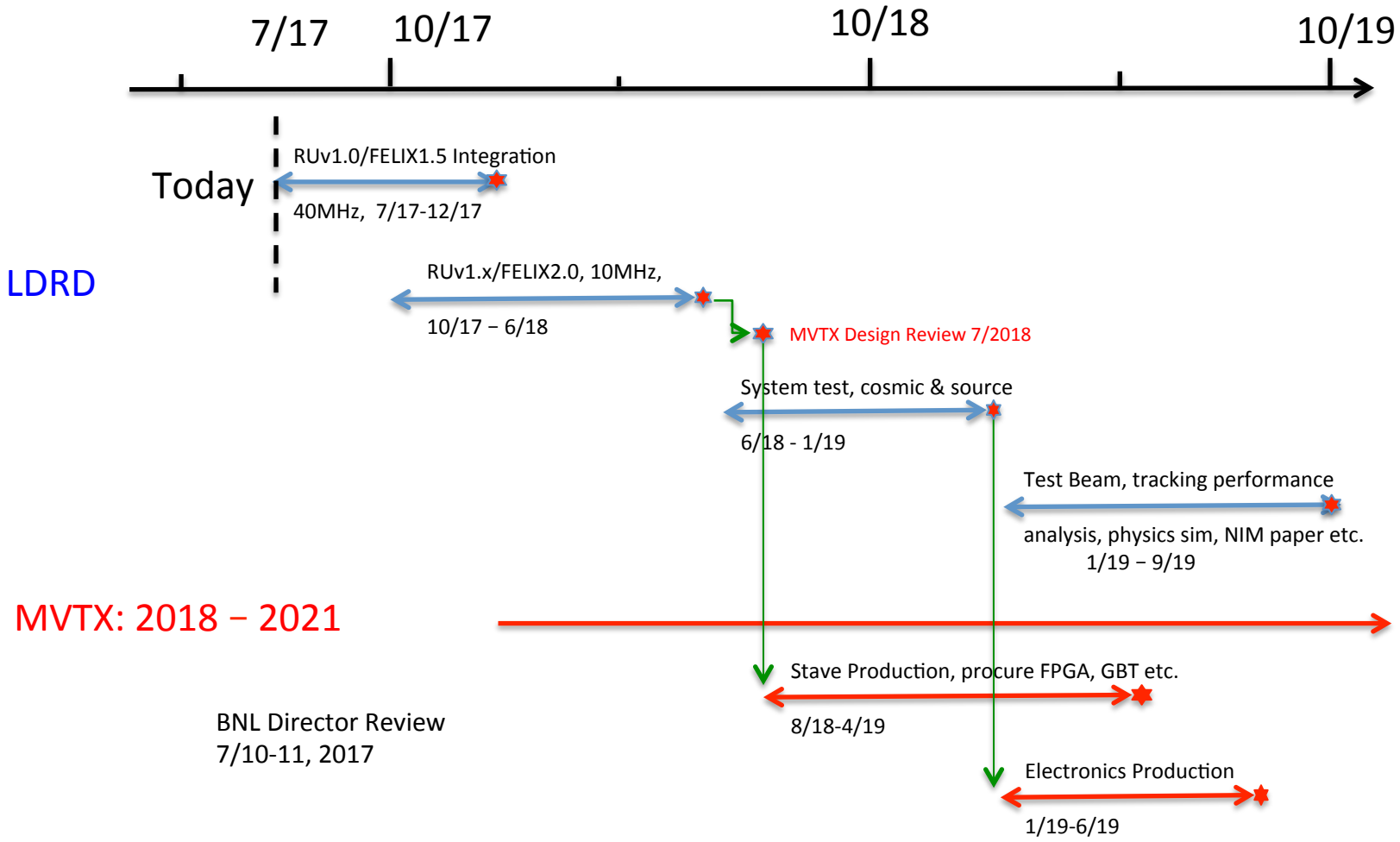
- Precision vertexing for b-jet/B-hadron tagging in HI with high efficiency and high purity
- B-jet modification in QGP at low-medium pT to determine QGP properties, study mass-dependence on collisional vs radiative energy loss, flow etc.

- Early R&D by LANL LDRD, $5M, FY17-19, readout, mechanical design and physics; established LANL-ALICE MoU for joint R&D and training

Scope of the MVTX Project

- MAPS Staves & Electronics
  - Produce 68 ITS inner Barrel Staves
    - No modification
  - Readout Electronics R&D (LANL LDRD)
    - Frontend: ALICE/ITS, RU
    - Backend: ATLAS FELIX
    - Modify/reprogram RU & FELIX for sPHENIX
  - Production:
    - Extend ALICE/ITS MAPS stave production
      - WBS 1.5.3.1, LANL
      - sPHENIX personnel help at CERN
    - Reproduce additional ALICE/RU & ATLAS/ FELIX
      - WBS 1.5.2.1, UT-Austin
      - WBS 1.5.2.2 , LANL
    - Final assembly and test in US
      - WBS 1.5.3, LBNL
  - Ancillary systems, "adopt" ALICE system
    - Power distribution, cables, crates, racks etc.,
      - WBS 1.5.2.3, LBNL
    - Slow control, safety and monitoring
- Mechanics & Cooling
  - Some changes to ALICE/ITS inner tracker mechanical structures, WBS 1.5.3
    - End Wheels
    - Cylindrical structure shells
    - Detector half barrels
    - Detector and Service half barrels
  - Mechanical Integration, WBS 1.5.4
    - **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
    - Smaller heat load than ALICE ITS
  - Metrology and Survey

LDRD – MVTX Key Tasks/Milestones



LANL LDRD Progress Highlights

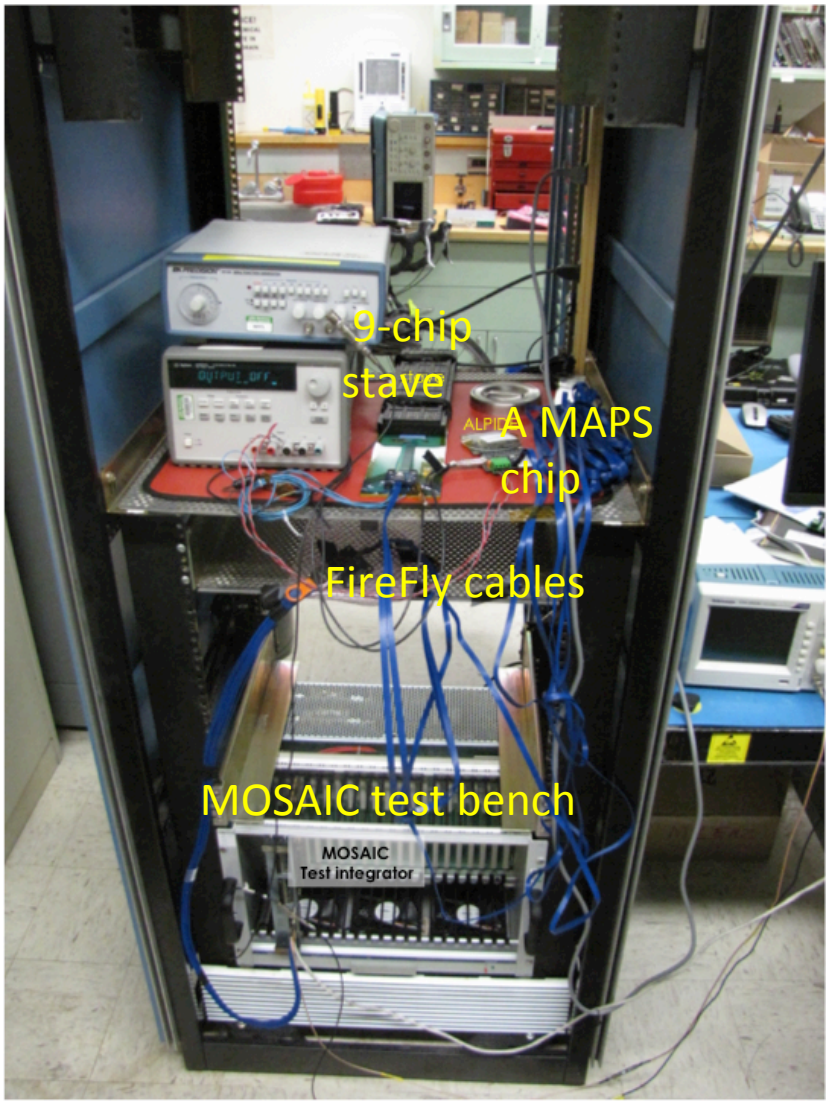
LDRD Goals:

- Complete MVTX readout design and development
- Preliminary conceptual design of mechanical system integration

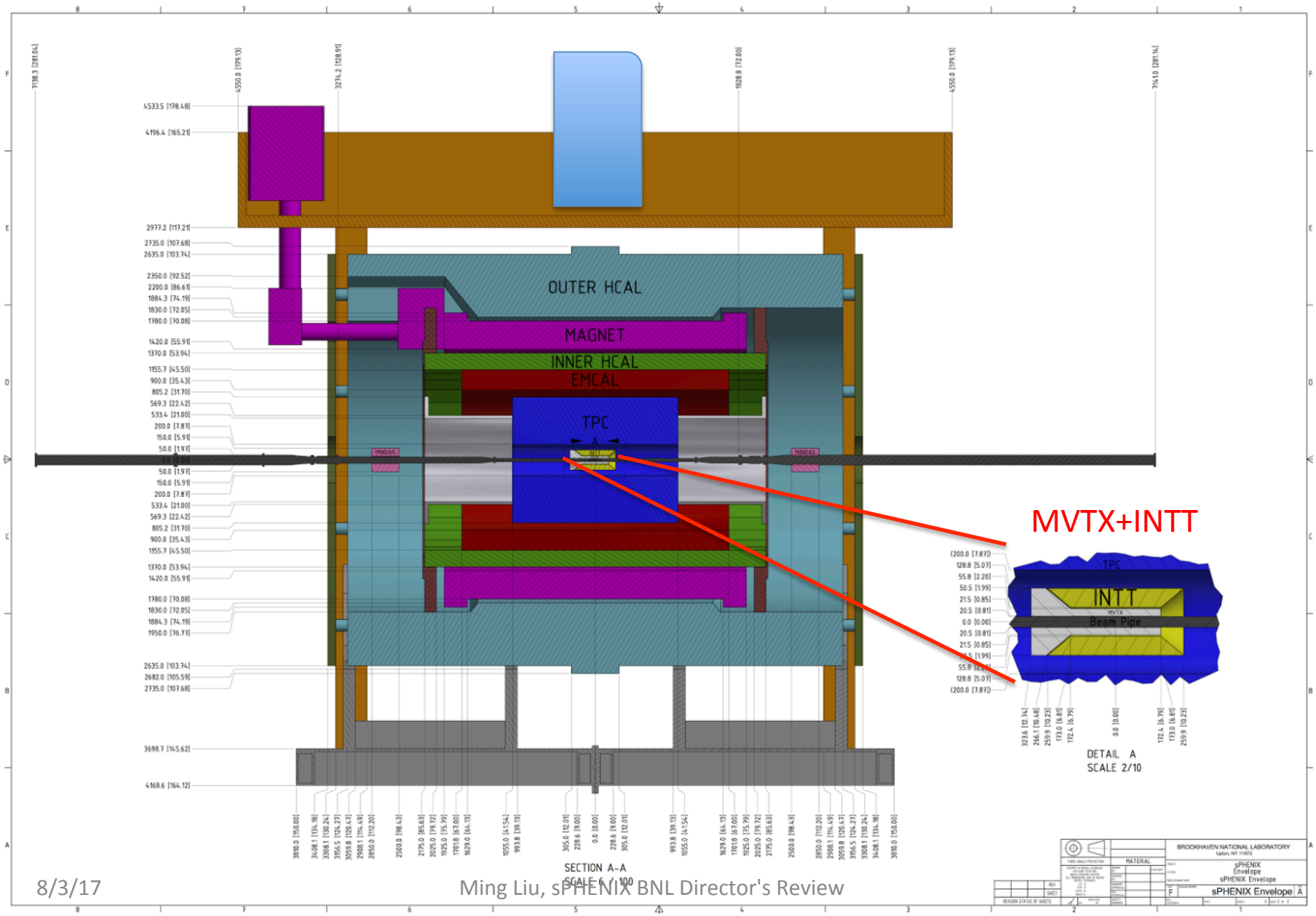
R&D status:

- MOSAIC test bench in operation
  - Single MAPS chip high-speed readout
  - 9-chip HIC/"stave" readout
  - External trigger, cosmic and source
  - Test data readout performance
    - 0.4, 0.6, 1.2Gb/sec
- Firefly cable performance test
  - 5m (ALICE default)
  - 7m, 10m (favored for sPHENIX)
  - Short extension cables, 20~30cm (share space with INTT), for mechanical system integration

- Back end FELIX board installed & being tested
- Front end Readout Unit boards available soon



MVTX System Integration

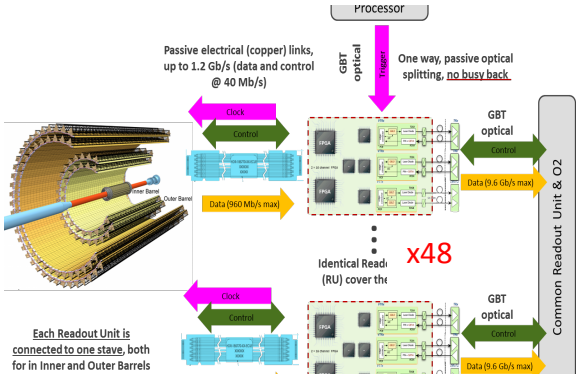


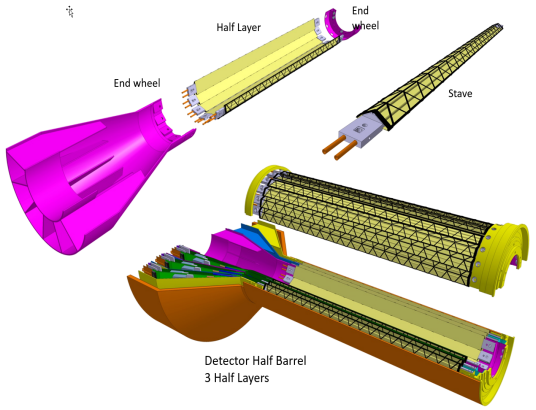
Cost Basis – Major Items

- Electronics (WBS 1.5.2): $1,285K
  - ALICE ITS RU & PS
  - ATLAS FELIX
  - Power system and controls
  - PHENIX/STAR/ALICE experience

- MAPS and Detector (WBS 1.5.3): $2,900K
  - ALICE ITS/IB production
  - PHENIX/ALICE/STAR experience

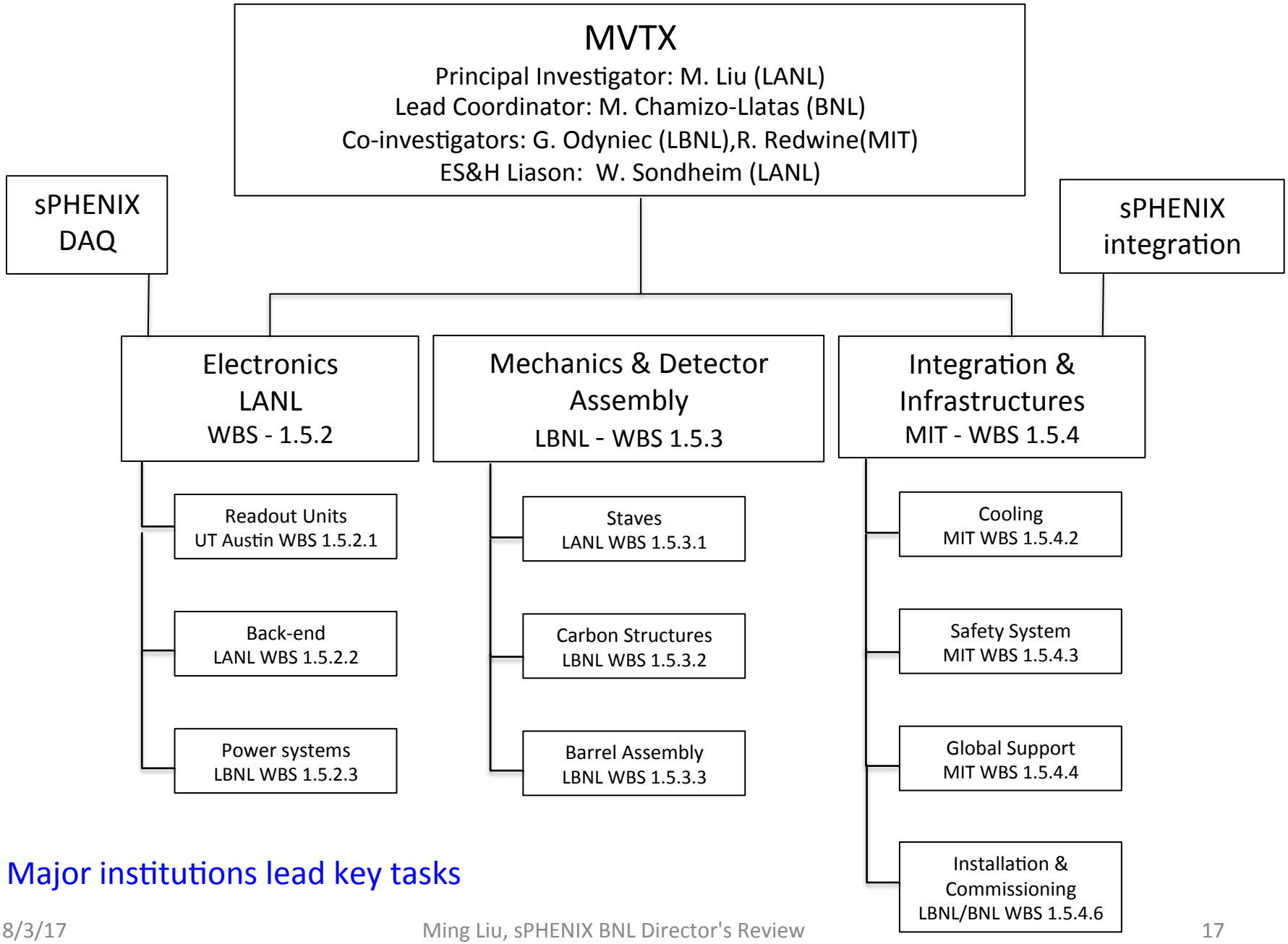
- Mechanical integration (WBS 1.5.4): $910K
  - ALICE ITS inner tracker design modification
  - FVTX/PHENIX, HFT/STAR experience





Total project cost: $5.7M, w/ 35% Cont.

Updated material and labor cost and contingency from pre-proposal
- latest quotes on electronics and other R&D items



Major institutions lead key tasks

A growing collaboration!

new sPHENIX/MVTX members:

- Czech groups: Charles Univ. and Inst. of Phys. of the Czech Academy of Sciences
  - Stave production at CERN

- CCNU – MAPS lab
  - HICs assembly and test
  - Mechanic integration

Potential collaborators:

- USTC
  - Physics simulations w/ LBNL
- Peking Univ.
  - Physics and detector simulations w/LANL
- NCU, Taiwan

From MVTX pre-proposal

7 Organization and Collaboration

Here we discuss the current collaborating institutions and their focus areas. Based on their technical expertise and available resources, LANL, LBNL and MIT/Bates groups are leading the three major technical tasks of the project: 1) readout electronics integration; 2)carbon mechanical support frames production and 3) cooling and mechanical system integration, respectively.

Los Alamos National Lab (LANL) : Readout electronics and mechanics integration.

Lawrence Berkeley National Lab (LBNL) : Carbon structure, production, LV and HV power system, full detector assembly and test.

Brookhaven National Lab (BNL) : System integration and services, safety and monitoring.

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

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

University of Texas at Austin (UT Austin) : MVTX readout electronics integration and testing.

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

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

Florida State University (FSU) : Offline and simulations.

University of New Mexico (UNM) : LV cabling & connectors.

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

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

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

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

Yonsei University (Korea) : MAPS chips QA and readout, simulations

RIKEN/RBRC (Japan) : Mechanical integration, cooling, cabling, simulation, patter recognition.

Purdue: Detector assembly and testing, analysis. Silicon lab available.

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

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

Status, Plans and Issues

- LANL- ALICE MoU
  - Associate member of ALICE ITS Upgrade project
  - Obtained ALICE readout test stand, MAPS sensors, staves and electronics for early R&D
  - Obtained design files, electronics and mechanics
  - Training sPHENIX personnel
- High Level Agreement with ALICE − on going discussions
  - Produce 68 staves for sPHENIX using ALICE/CERN facilities

- Potential schedule/funding gap of stave production
  - ITS/IB production: 7/2017 - 6/2018
  - If funding significantly delayed, concerns over the availability of CERN facilities
  - Risk Mitigation:
    1. Early training through LDRD effort, maintain activity at low level
    2. External foreign funding, CCNU Pixel Lab etc.
    3. Possible “mortgage” for sPHENIX production from ALICE/CERN with “Agreement”
- sPHENIX readout and mechanical integration R&D
  - Schedule risks due to unavailability of key R&D elements like staves and readout electronics
  - MVTX/INTT integration
  - Risk mitigation:
    - Early joint R&D with ALICE as associate members
    - Early R&D with prototype staves, RU and FELIX
    - Early mechanical system integration R&D

Summary: Project Tasks and Timeline

sPHENIX baseline

CD-0
9/2016

CD-1?

Ready for Beam, 2022?

Readout R&D
Mech. design
@LANL/ALICE/UT-A

ALICE ITS/IB prod. ends

Key R&D
LDRD@LANL

Mech. Integr.
& Prototype
@LANL/MIT/LBNL

A schedule driven project!

Production

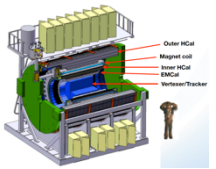
MAPS Prod. & QA
@ALICE

Stave prod.&test @CERN;
C-Stru. Prod. @LBNL

"RU" & "FELIX"
Prod. @US

Detector Assembly
& Test @LBNL

Det. Install.
@BNL



Backup

INTT-MVTX Conflict

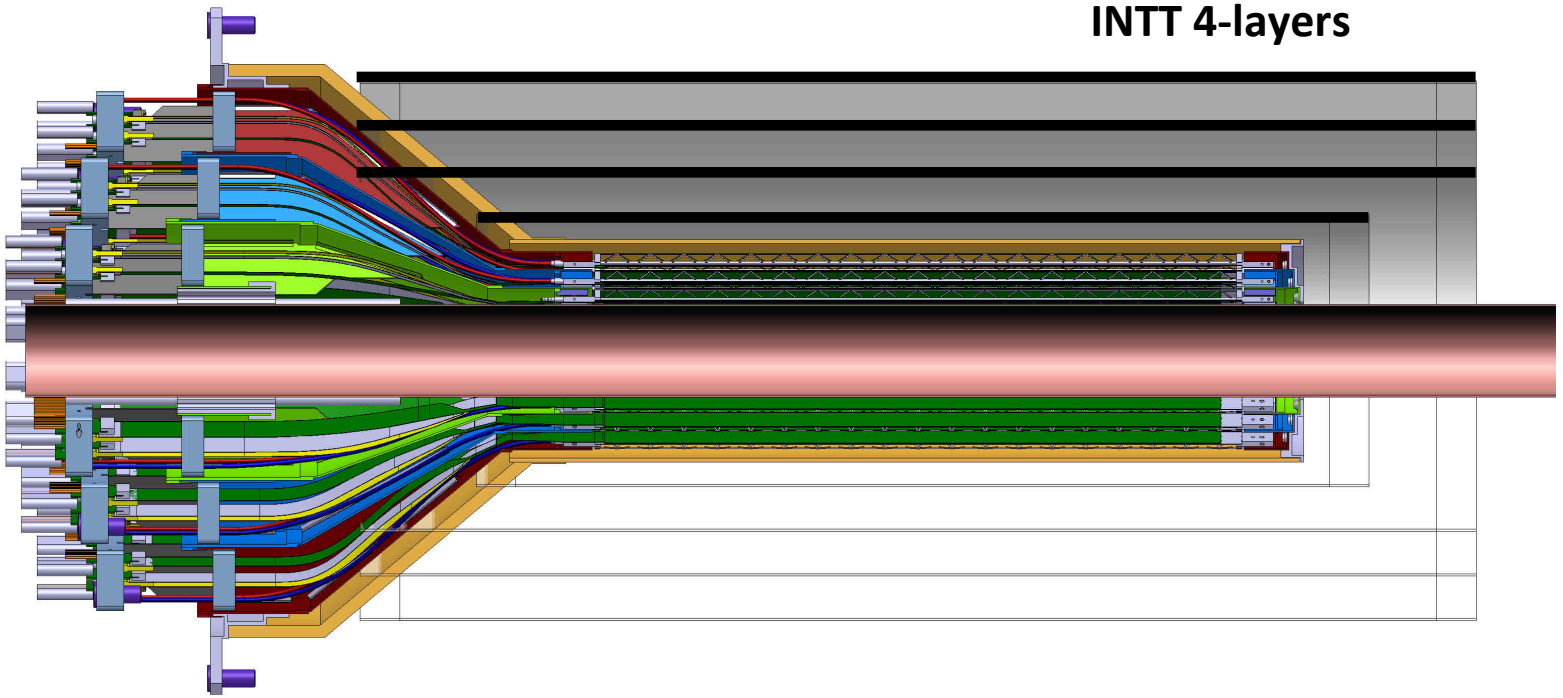
INTT Acceptance @ |z|=10

|η|<0.95

|η|<1.09

|η|<1.28

|η|<1.12

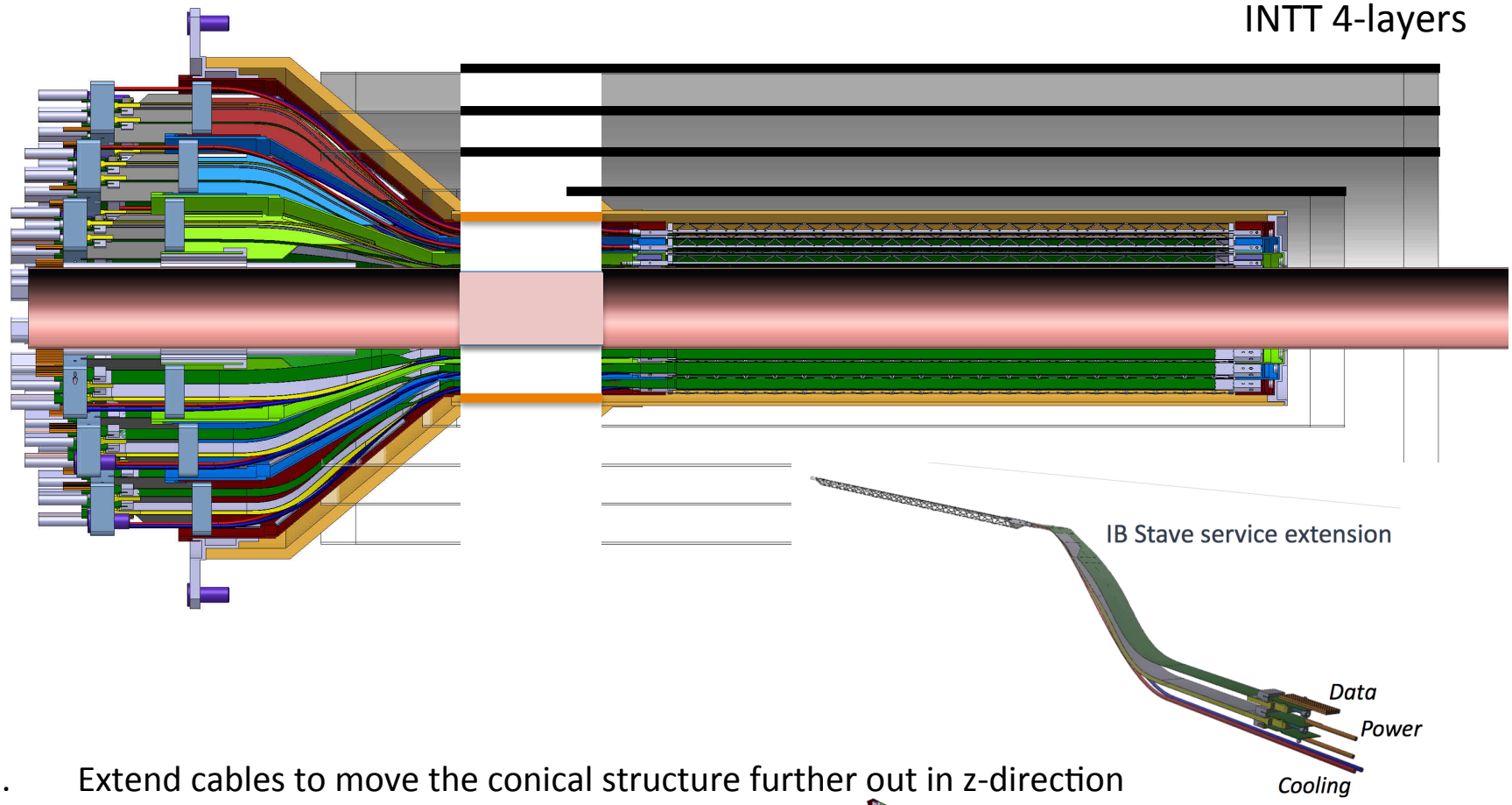


- Currently a clear conflict between the INTT and MVTX
  - INTT only includes ladder, no connectors, cooling barbs, etc

R&D items: 1) Extend cables to move the conical structure further out in z-direction; 2) Design/optimize INTT layers to fit current MVTX geometry;

- FPC data cable is the HDI and can't be easily extended, short "firefly" cables possible?
- Reduce angle of cone − redesign C-structures and connectors

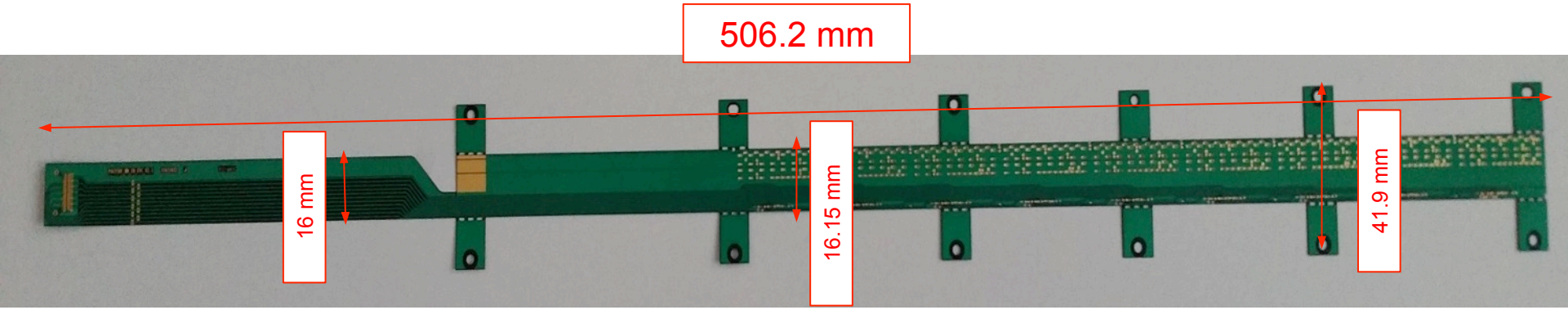
INTT-MVTX Conflict

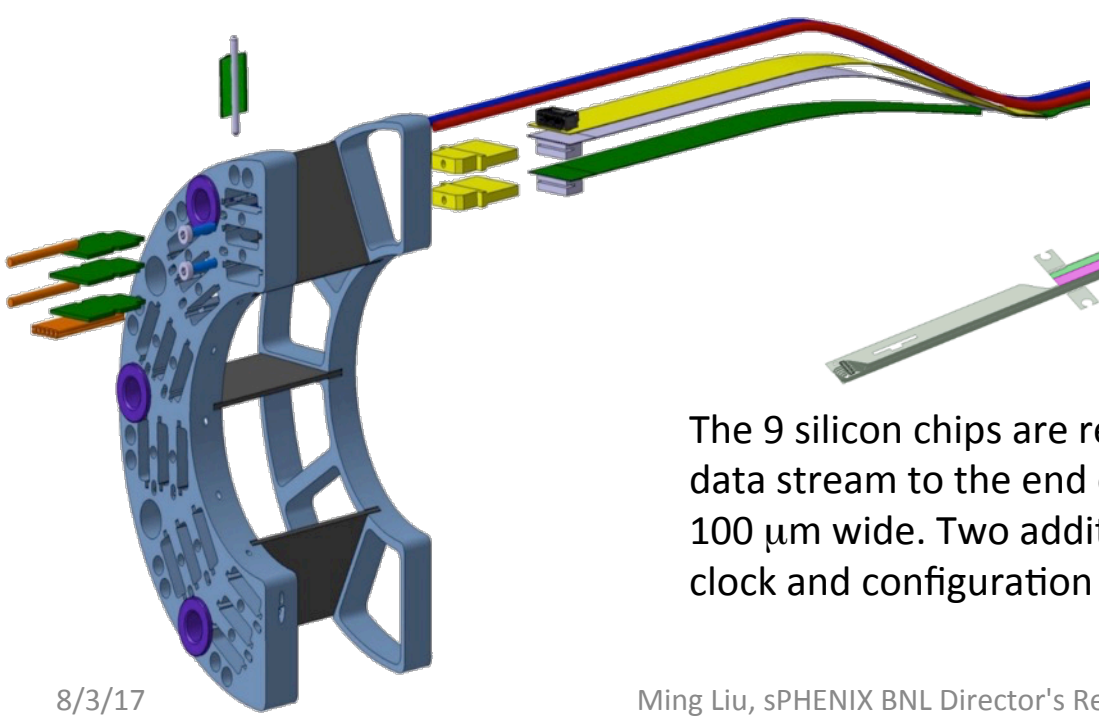


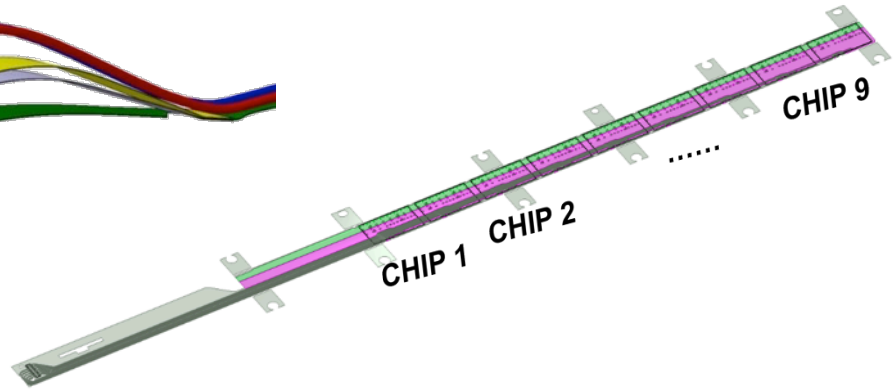
1. Extend cables to move the conical structure further out in z-direction
   - FPC data cable is the HDI and can't be easily extended
   - Possibly add short "firefly" cables to hook up to patch panel, R&D needed
2. Reduce angle of cone − redesign

MVTX/INTT Integration

Extend MVTX Service Cables?



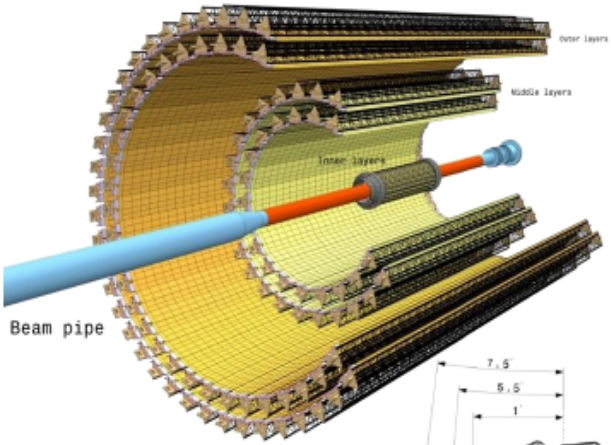


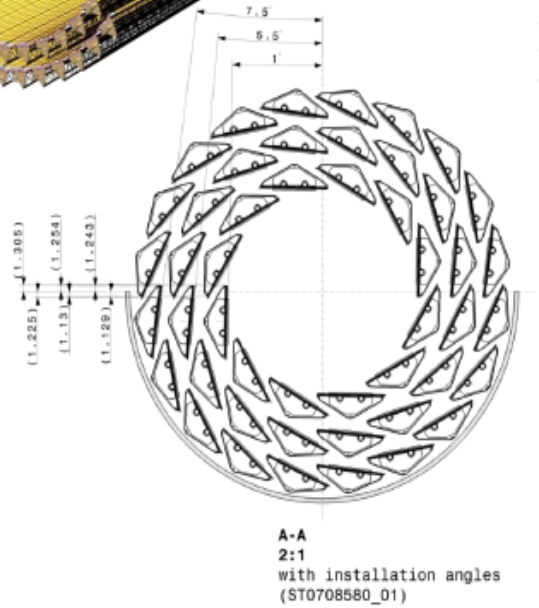


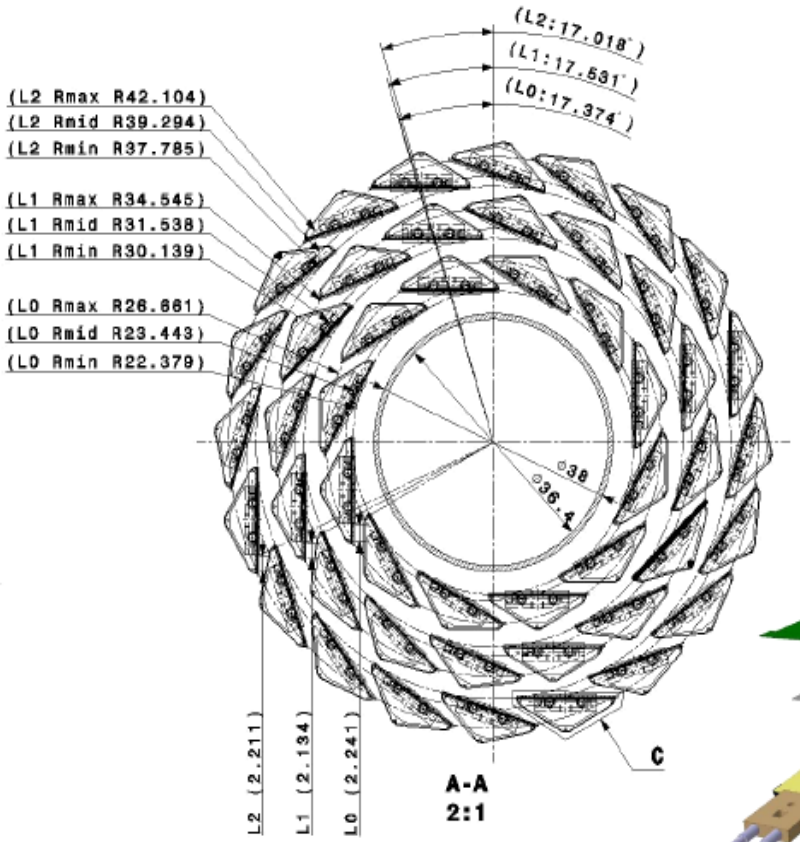
The 9 silicon chips are read out in parallel: each chip sends its data stream to the end of Stave by a dedicated differential pair, 100 μm wide. Two additional differential pairs distribute the clock and configuration signals.

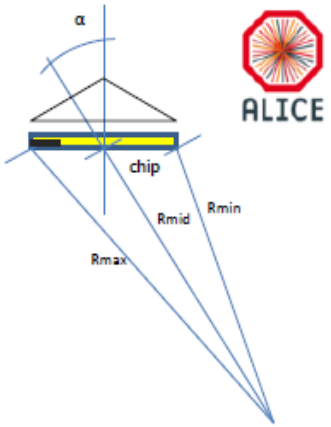
ITS layout: coverage, layers 0-1-2

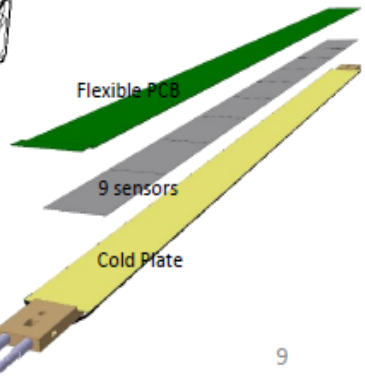
…from 22mm to 42mm radius



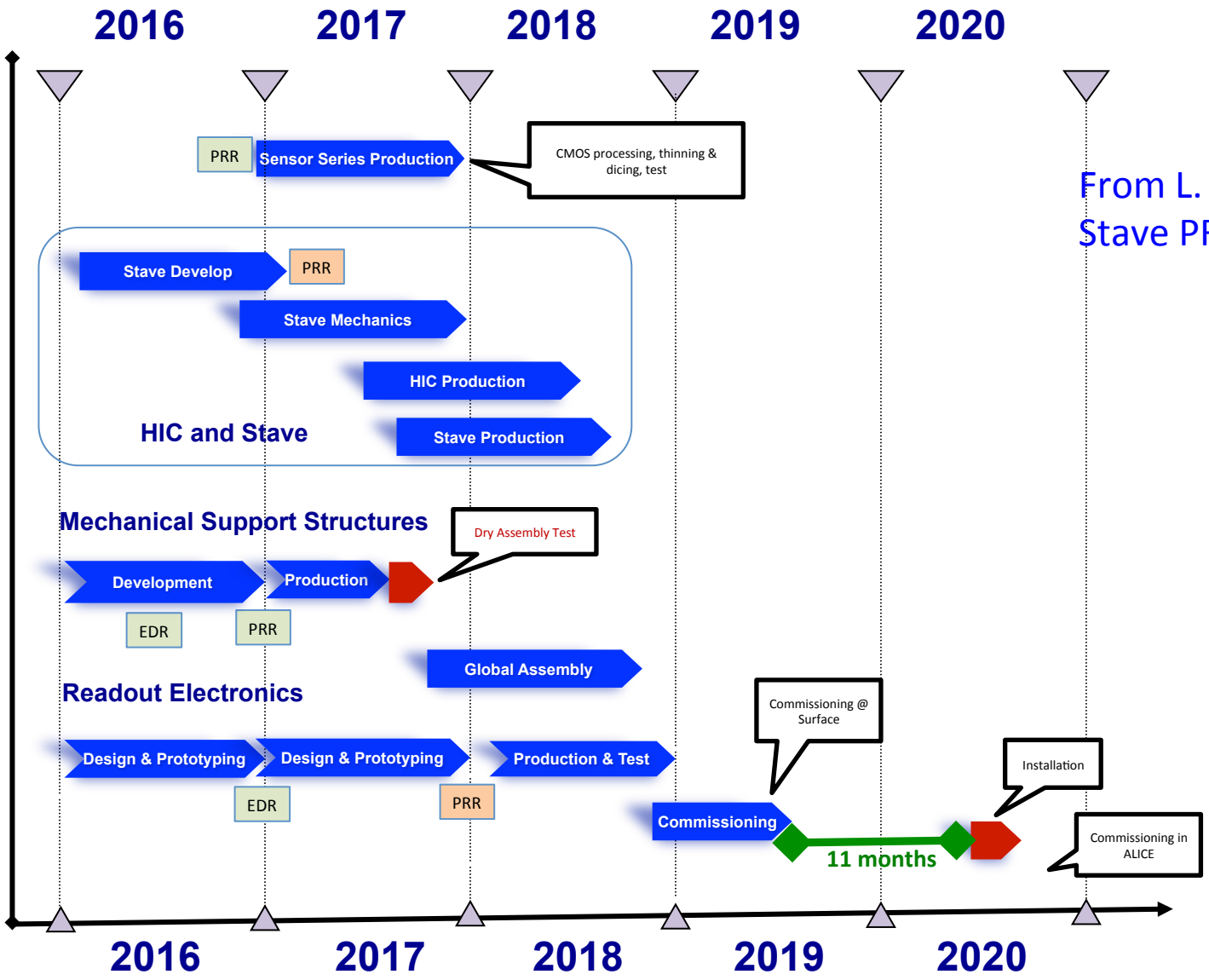








Overall ITS Planning (Simplified Global View)



From L. Musa, 4/27/2017
Stave PRR Presentation

Project Review Milestones

From L. Musa, 4/27/2017

① Pixel Sensor Chip - EDR (Oct' 15)
② Stave - EDR (May' 16)
③ Detector Barrel Mechanics - EDR (Jul '16)
④ Cooling – EDR (Jul '16)
⑤ Pixel Sensor Chip - PRR (Nov '16)
⑥ Detector Barrel Mechanics - PRR (Dec '16)
⑦ Service Barrel Mechanics - EDR (Dec '16): done
⑧ Cooling – PRR (Dec '16): done
⑨ Readout Electronics – EDR (Jan '17): done
⑩ Stave - PRR (Apr '17)
11 Service Barrel Mechanics – PRR (May '17)
12 Readout Electronics – PRR (Dec '17)

Stave Production Readiness Review:
4/27/2017

- Stave production starts ~May/June;
- 1st set of IB by Jan 2018;
- 2nd set of IB by July 2018
- LANL people + others/MVTX work on stave production from May 2017 at CERN, prototype available soon at LANL

- Fully working staves for R&D available ~Jan 2018;
- Near final readout RU/CRU: ~12/2017