MVTX Status and Plan

Ming Liu

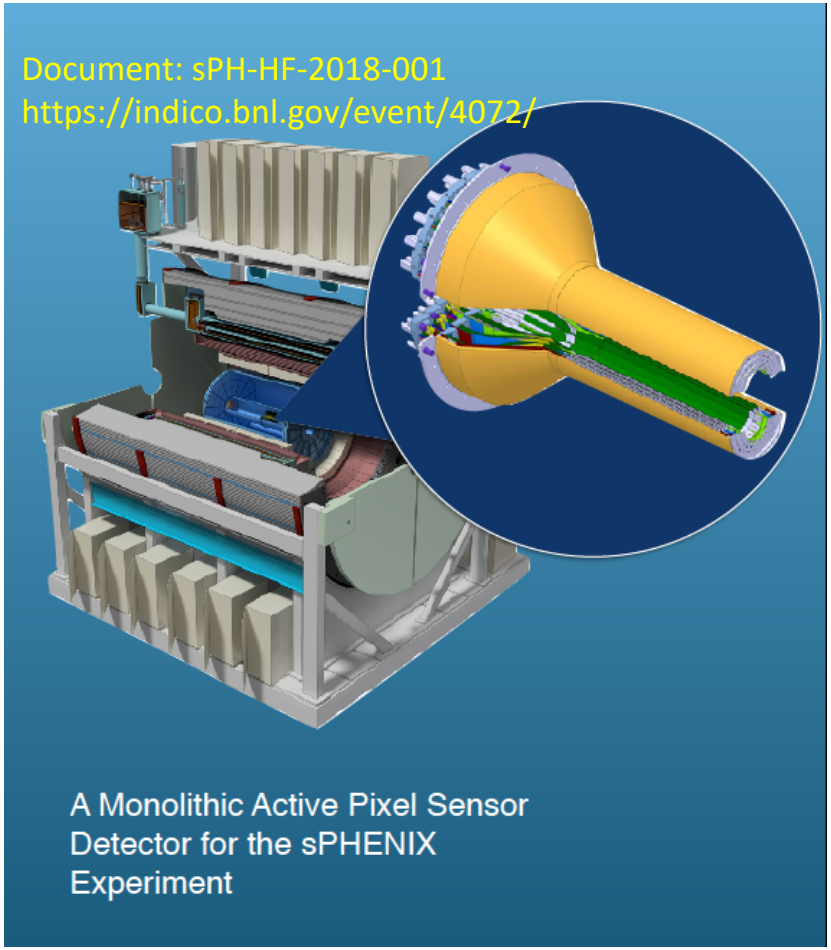
For the MVTX Detector Group

06/06/2018

sPHENIX Collaboration Meeting

Outline

- Project Status
- MVTX full proposal
- R&D Highlights
- Plan



Toward Realizing MVTX …

A Short Summary …

From Dave & Gunther talk

Realizing MVTX

- Good: Collaboration completed and submitted very strong MVTX proposal at beginning of year **Feb. 2018**
- Bad: DOE did not accept upgrade proposal: No "new" funding for sPHENIX outside of RHIC operations
  - "No expectation of bulk funding from DOE"
- Good: DOE recognized the importance of MVTX to science program; encouraged us to secure alternative funding sources
- Bad: Presidential budget presented bleak fiscal outlook
- Scheduled MVTX workfest at MIT for late April to explore all options

Realizing MVTX, cntd.

- Good: Actual budget presented unexpectedly excellent news for science, NP, RHIC

Yesterday Congress released the high-level numbers and language for the FY2018 budget omnibus bill. They are fantastically good:

NP gets $684M, which is $62M more than in FY2017. The language stipulates "optimizing operations of RHIC, CEBAF, ATLAS and BLIP.

This could hardly be better (it means that NP is back on the modest growth scenario, maybe even slightly better) and also portends very well for FY2019.

Berndt

- Good: '17 budget maneuvers (oHCAL steel) presented room in CD-0 cost range to include MVTX
- Good: At time of MVTX workfest, funding MVTX through same mechanisms as MIE appears feasible

- sPHENIX workshop in China, 4/2018
- Korean consortium under discussion, led by Prof. Y. Kown

- Extensive discussion of integration @MIT
- MVTX+INTT+TPC…

https://indico.bnl.gov/event/4380/

MVTX Status: Where do we stand?

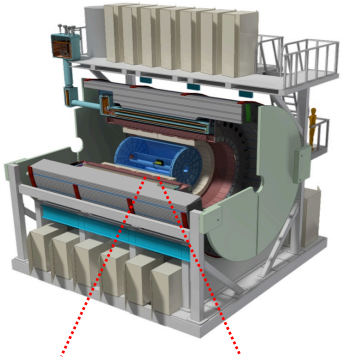
- BNL (w/ DOE) is actively exploring ways to secure funding for MVTX
  - sPHENIX MIE at CD-2 (when baseline defined)
  - Or a parallel project

- BNL/MIT facilitating advanced funding for stave and RU production beginning Oct. 2018
  - MVTX/INTT subsystem integration mini-review planned for 7/19/2018
  - Procurement readiness review in September 2018

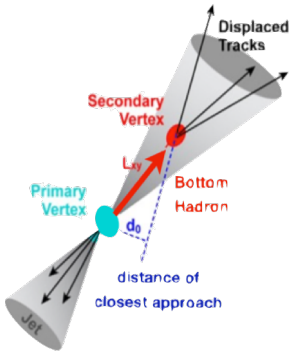
MVTX Full Proposal

MVTX: Monolithic-Active-Pixel-Sensor-based VerTeX Detector

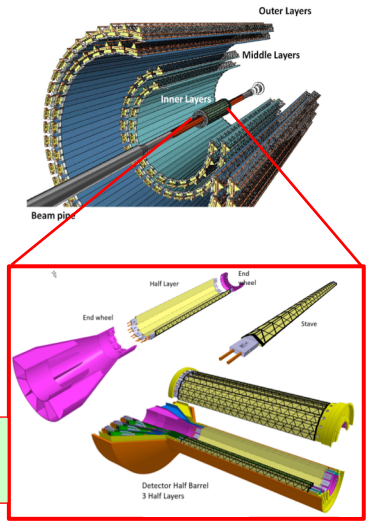
sPHENIX @RHIC



Key integration tasks:
- Readout
- Mechanics



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



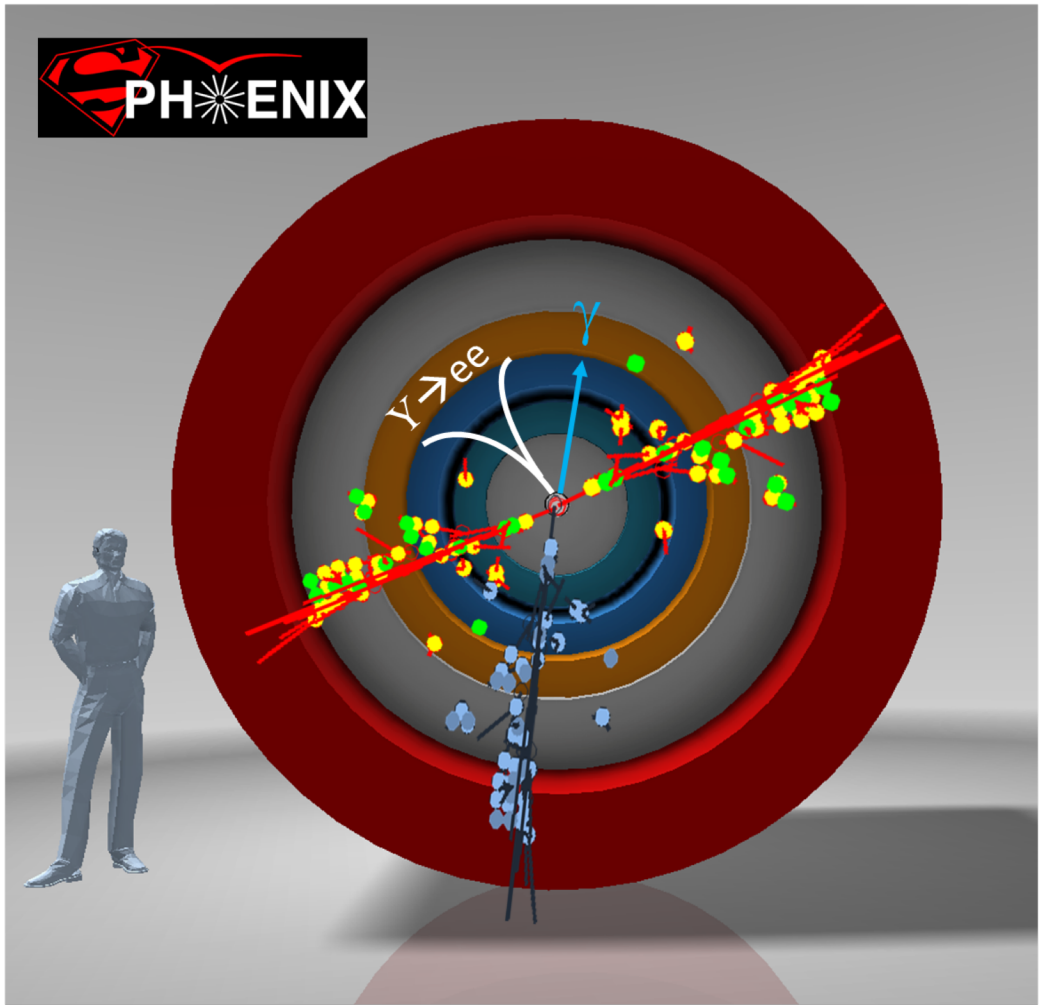
"Adopt" ALICE/ITS
Mini. risk,
Max. physics

MVTX could also be a day-1 EIC detector

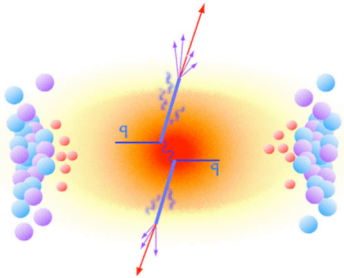
MVTX Enables the 3rd Science Pillar

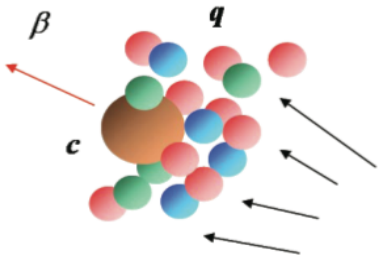
Jin/Xin's talk

1. Jets
2. Upsilons
3. Open Heavy Flavor



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

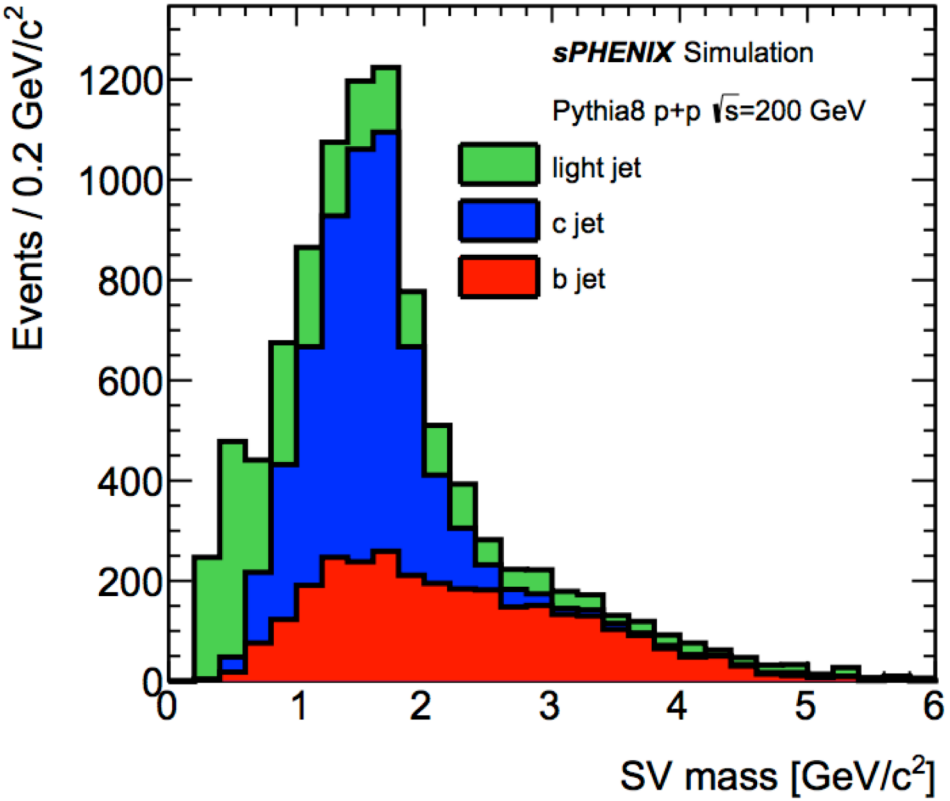


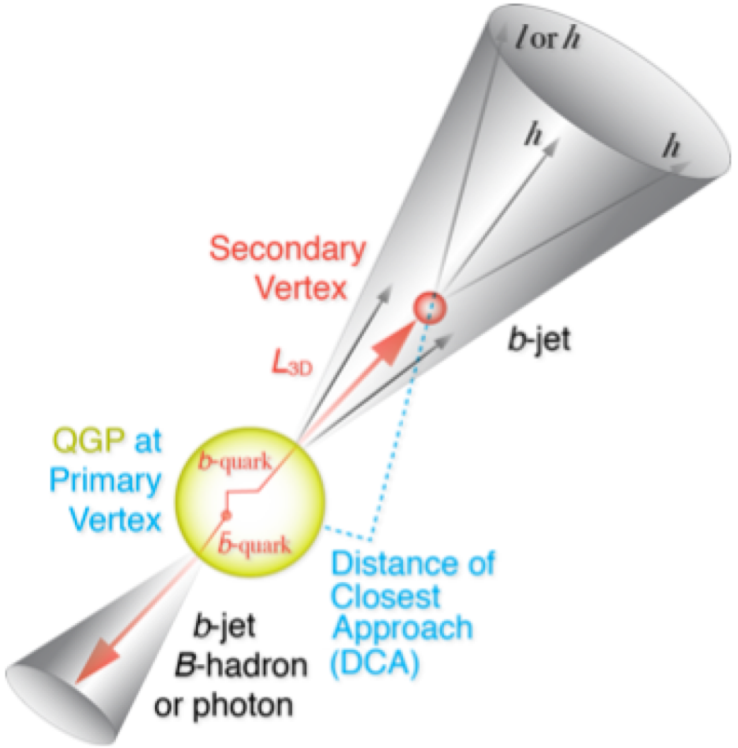


B-Hadron & b-Jet Tagging

Jin/Xin's talks

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



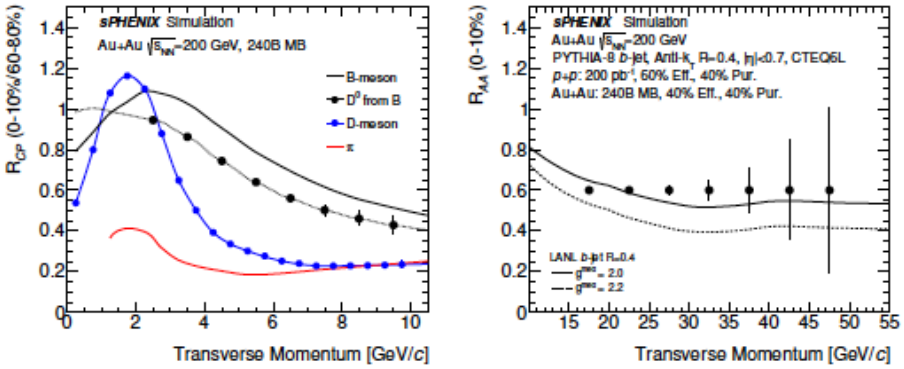


MVTX Physics Highlights

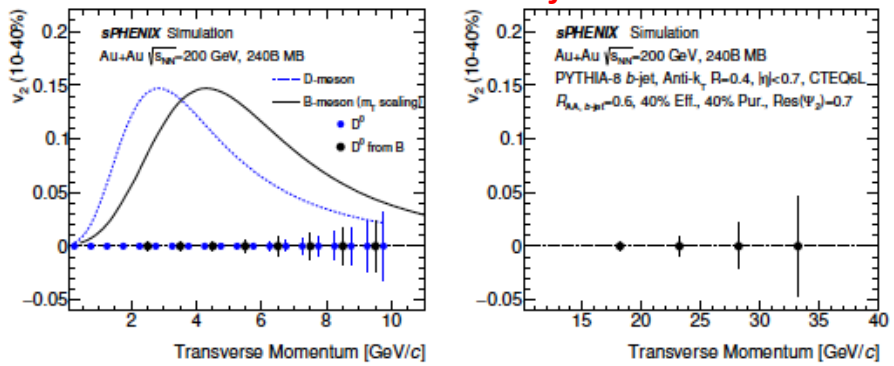
Jin/Xin's talk

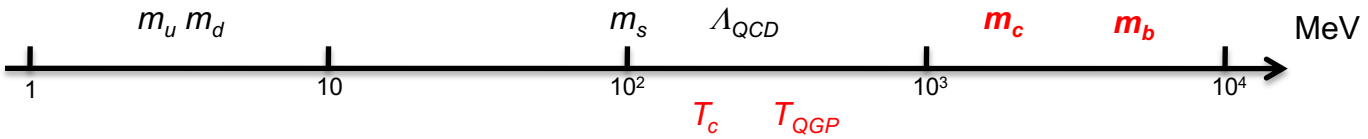
- Heavy quarks – unique probe of QGP w/ new scales, **m_c, m_b**
  - Study mass dependence
    - Jet quenching & energy loss
    - Flow – interaction with medium
  - Access QGP properties
    - Temperature, density, coupling, transport coefficients, viscosity etc.

"B meson and b-jet modification"



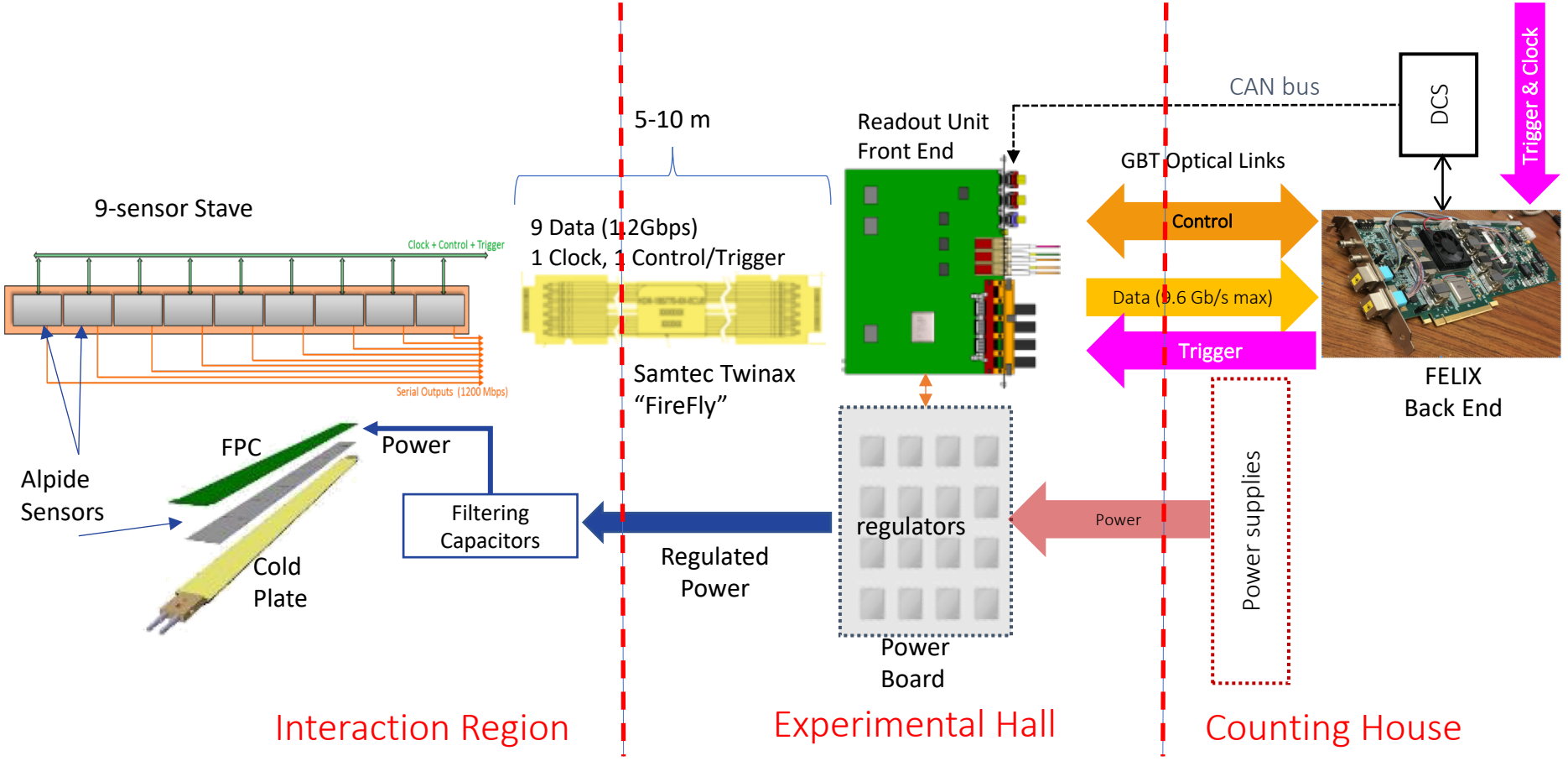
"B meson and b-jet flow"





R&D Progress and Highlights

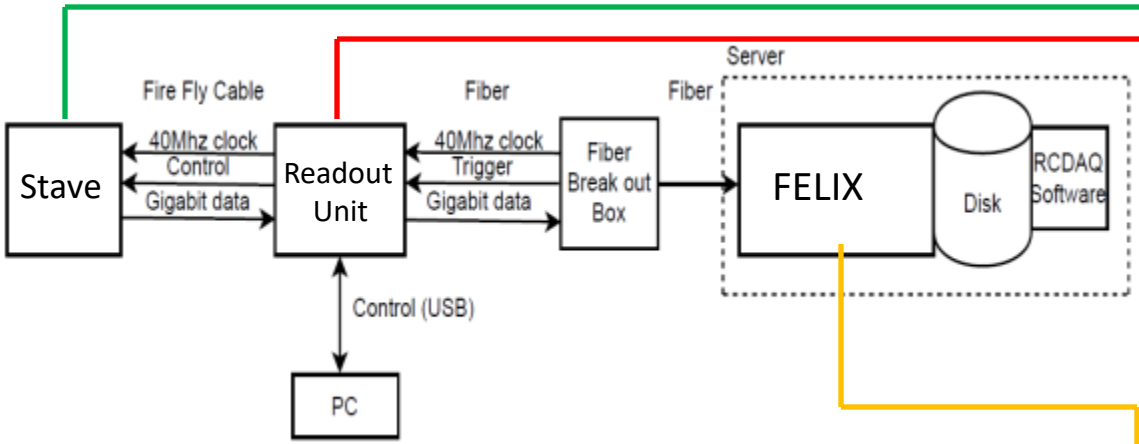
MVTX Electronics, Power and Controls

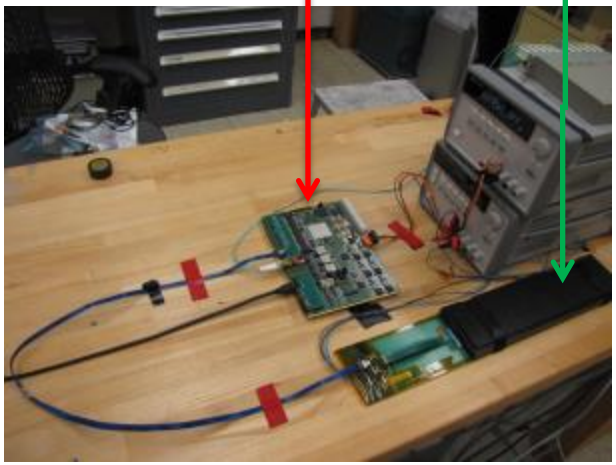


MVTX Detector Electronics consists of three parts

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

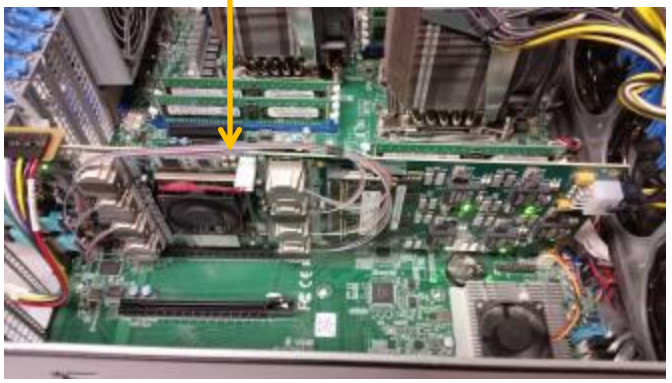
MVTX Full Readout Chain Demonstrated





Readout Unit + Stave

- Readout Unit configures Stave using USB interface
- FELIX distributes clock to Readout Unit
- Readout Unit distributes clock to the Stave
- Stave is triggered, sends data at 1.2Gb/s
- Configured GBT link to recover clock from FELIX
- Readout Unit receives the data and sends the data to FELIX over fiber using GBT link
- FELIX packs data, stores it on disk using RCDAQ - the sPHENIX data format and software

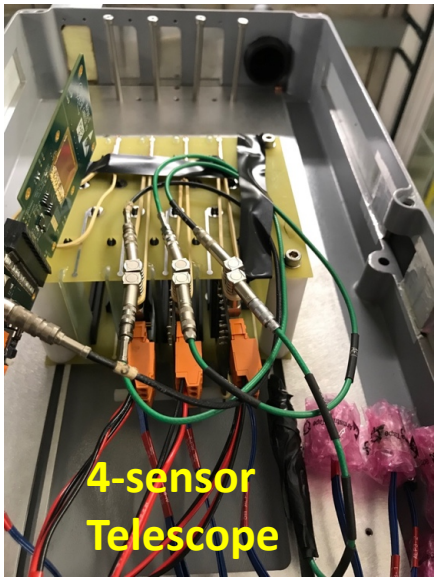


Server + FELIX

MVTX Test Beam at Fermilab 02/20-03/10, 2018

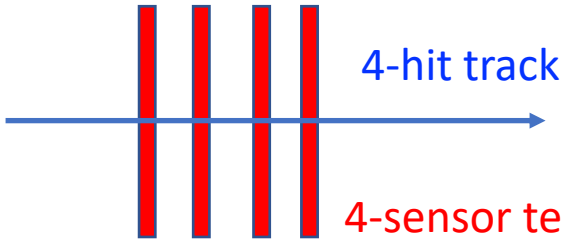
- Goals:
  - Test full readout chain
  - Evaluate ALPIDE sensor performance
- Experimental setup
  - A 4-sensor telescope
  - Full readout chain: MAPS+RU+FELIX+RCDAQ

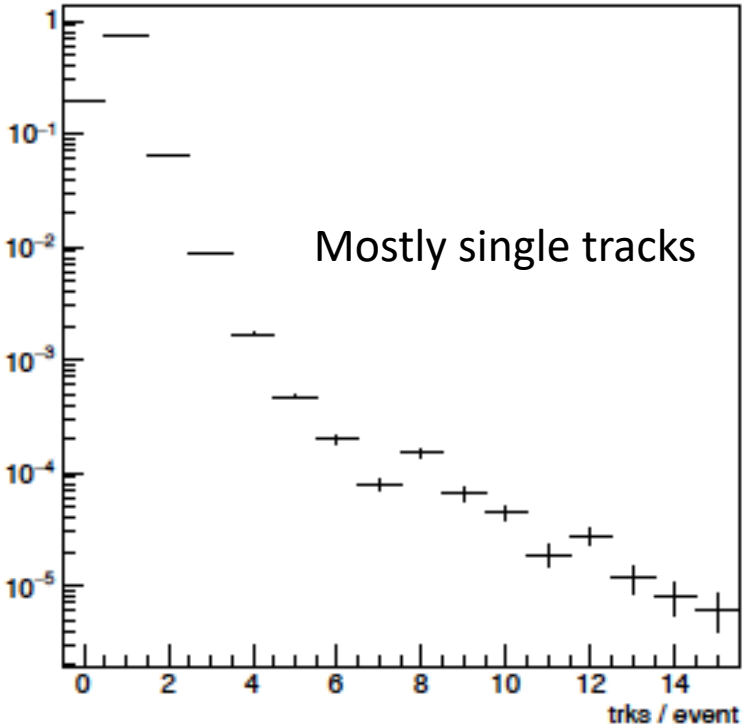
120 GeV proton



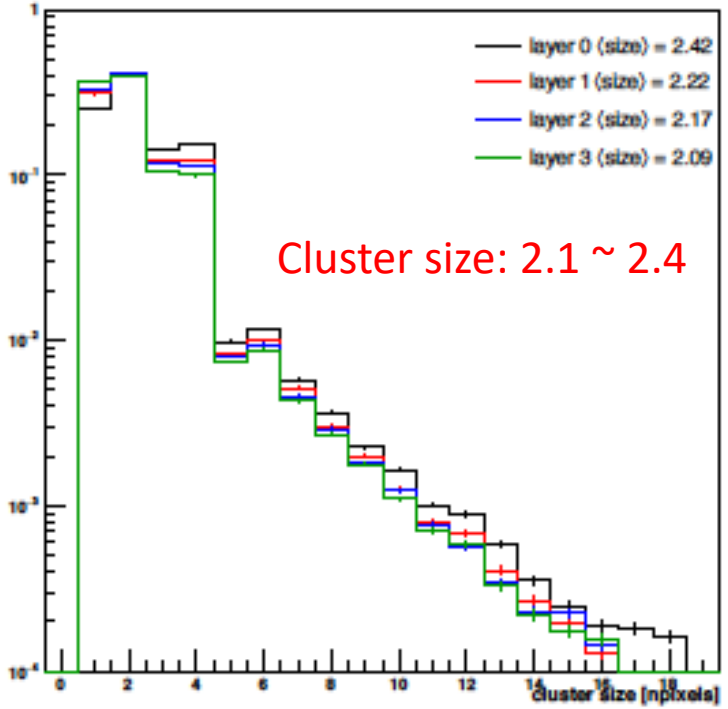
- Parasitic with INTT run
- Very productive & collaborative

Fermilab Test Beam Results (I)





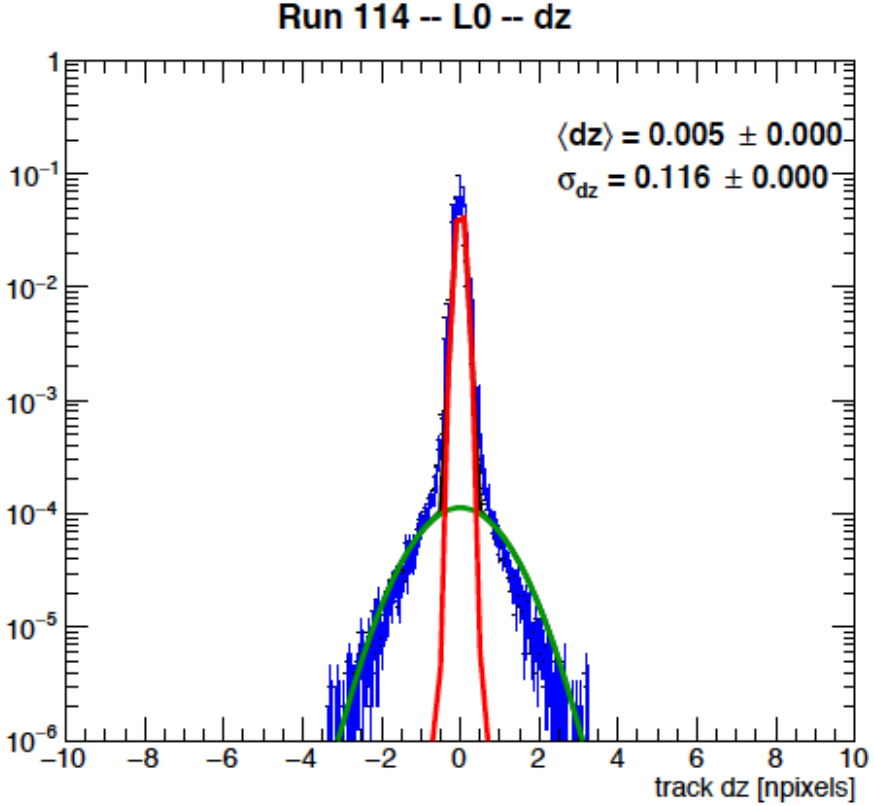
# of tracks per triggered event



Cluster size

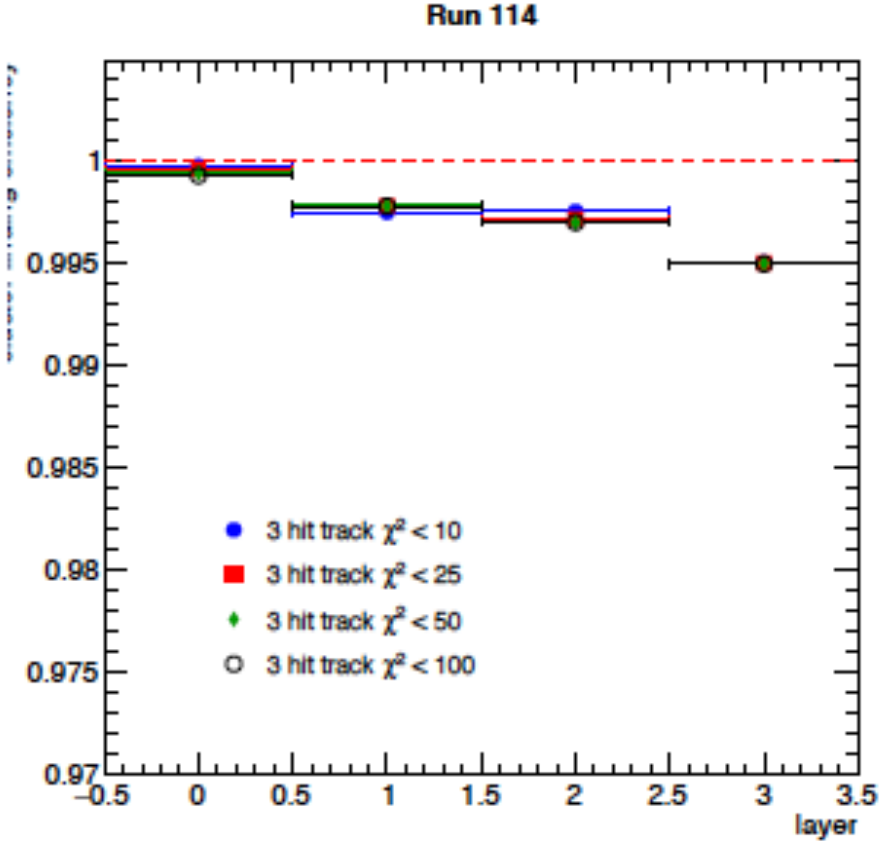
Fermilab Test Beam Results (II)

Hit Spatial Resolution: < 5 um



Pixel size (~28um)

Hit Efficiency > 99.5%

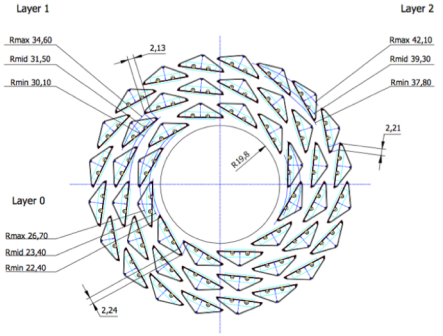


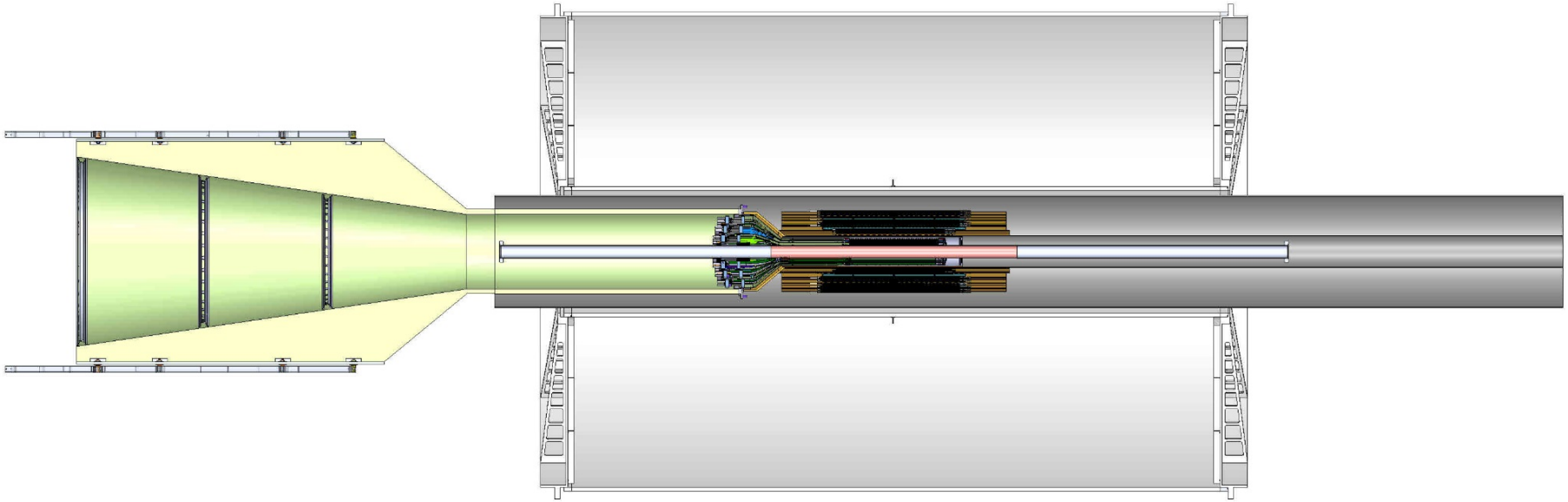
Mickey/Walt's talks

MVTX Detector Integration

- Electrical system
  - Readout, power, controls
- Mechanical system
  - Support and cooling
- Office of System Integration

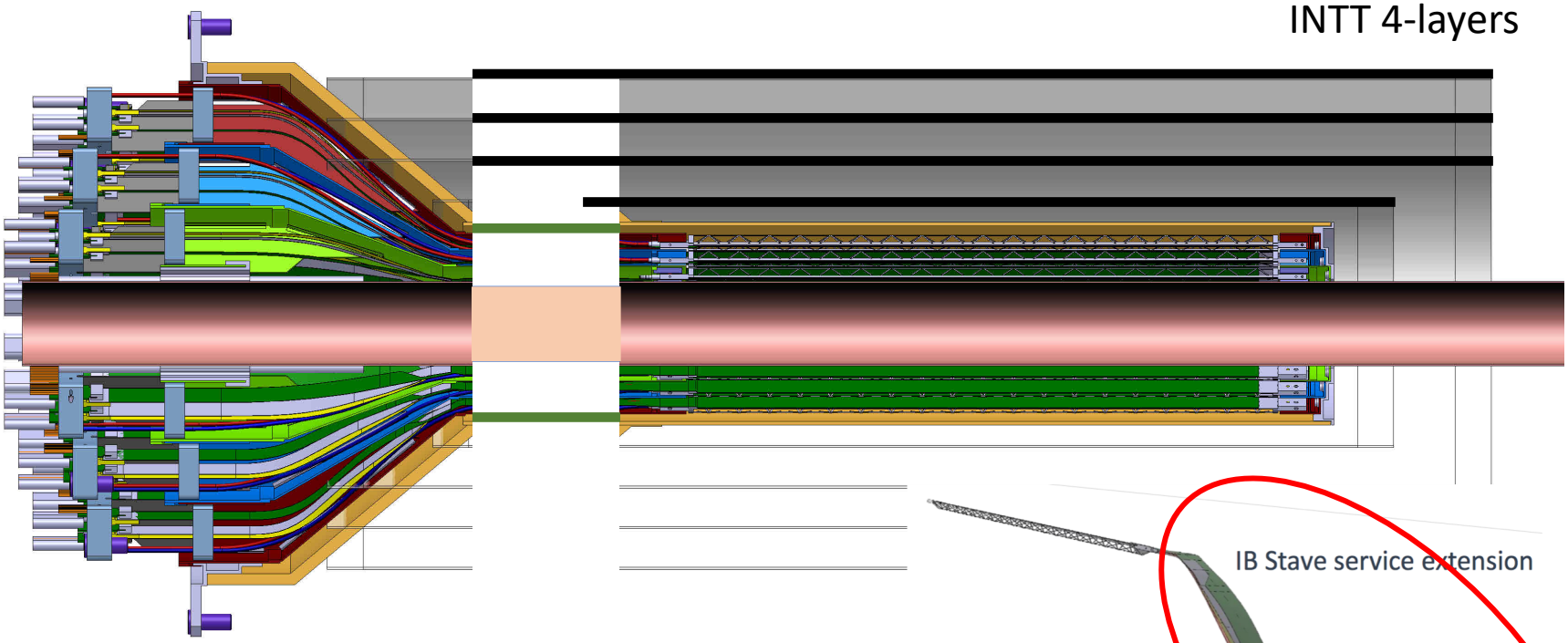
MVTX:
- **3 layers**
- **48 staves**

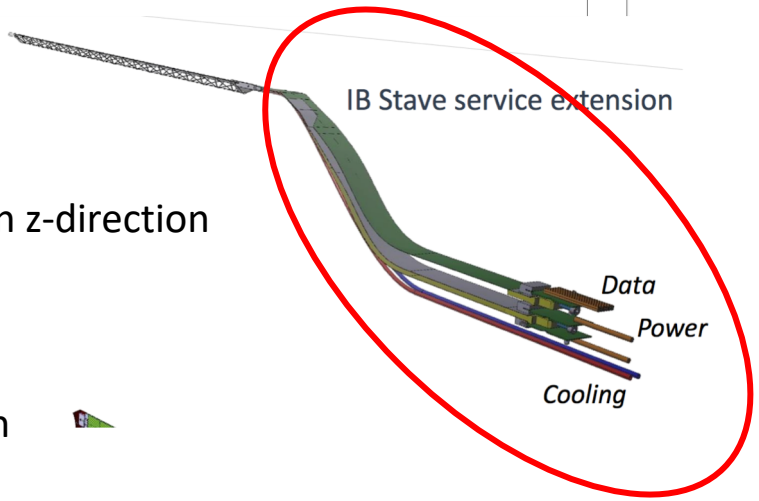




Walt/Mickey's talks

Toward INTT-MVTX Conflict Resolution



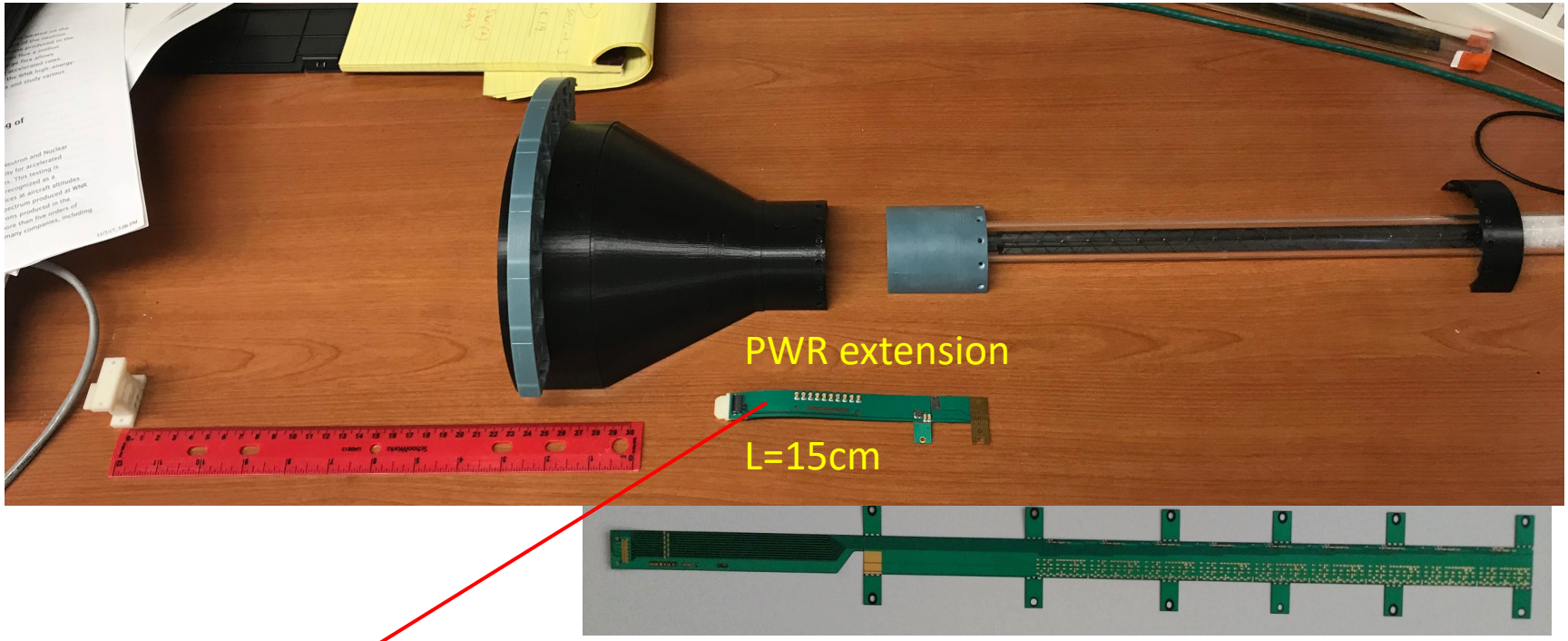


MVTX: Extend cables to move the conical structure further out in z-direction

- FPC data cable is the HDI and can't be easily extended
- Make longer power extension ~50cm (current: 15cm)
- Reduce angle of cone to free up space for INTT services
- Redesign patch panel/cable connection shape and location

INTT: optimize detector layout and support for integration

MVTX Mockup & FPC Extension R&D



Extended power cables AVDD/DVDD:
L = ~50cm, and possibly with 2~3 different lengths, like 30cm and 40cm
Separate PWR and signal connections at different Z-locations.

Plan for next 6+ months

- **Detector simulation for integration: INTT + MVTX + TPC … urgent!**
  - TPC-INTT-MVTX tracking optimization for integration
  - Physics performance study, 3 or 4-layer INTT etc.
- Mini-review, July 19
  - MVTX/INTT subsystem integration
  - Technical readiness of stave and RU for production
- Production readiness review in September
  - Stave and RU production at CERN beginning 10/2018
  - Advanced funding, BNL/MIT
  - MVTX + INTT + rest sPHENIX integration
- Near term R&D
  - MVTX carbon structure and integration
    - End wheels
    - Service barrel
  - Electrical system integration
    - Readout
    - Slow control & power
  - MVTX+INTT joint test beam at Fermilab, ~Feb/Mar 2019
- Budget profile & schedule smoothing
  - RHIC operation budget and cash flow
  - MVTX production schedule
  - Prepare for CD-2 MIE integration

Summary

- MVTX full proposal completed
  - Expanded science
  - sPHENIX baseline (CD-2)
  - New collaborators, on physics/software and hardware

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

- Cost and schedule being updated
  - Major item cost and production plan
  - Funding profile smoothing
  - Advanced funding for staves and RU production at CERN
- Excellent progress in R&D
  - Full readout and controls proof-of-principle demonstrated
  - Conceptual integrated mechanical system design developed
- MVTX+INTT+TPC integration in progress
  - Electrical and mechanical system
  - sPHENIX wide coordination through Office of System Integration
- To be ready for sPHENIX Day-1 Physics in 2023
  - sPHENIX and later EIC possibility

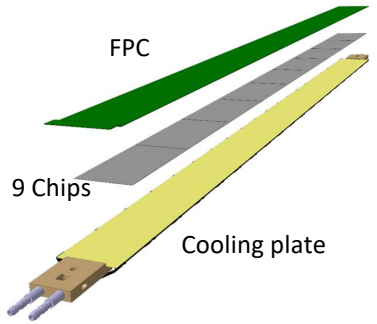
Backup slides

Monolithic-Active-Pixel-Sensors (MAPS)

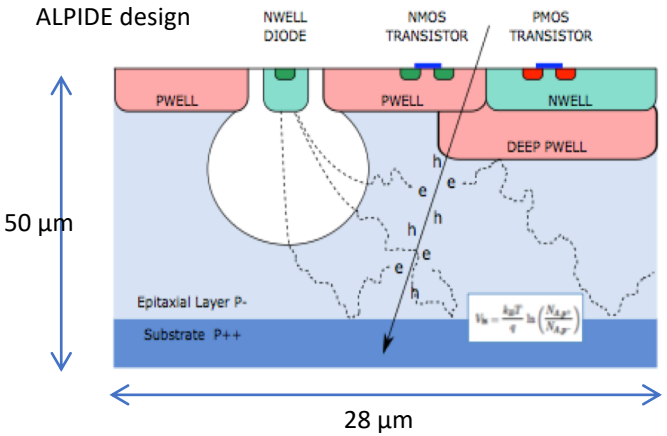
ALPIDE: The next Generation State of the Art Pixel Sensor

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

An ideal detector for sPHENIX and EIC physics!



A 9-chip MAPS stave, 9 x (1.5 x 3 cm^2)



Tower Jazz 0.18 µm CMOS

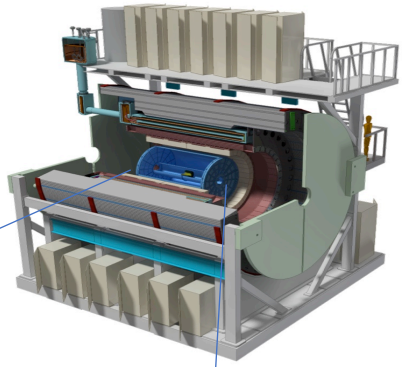
- feature size 180 nm
- metal layers 6
- gate oxide 3nm

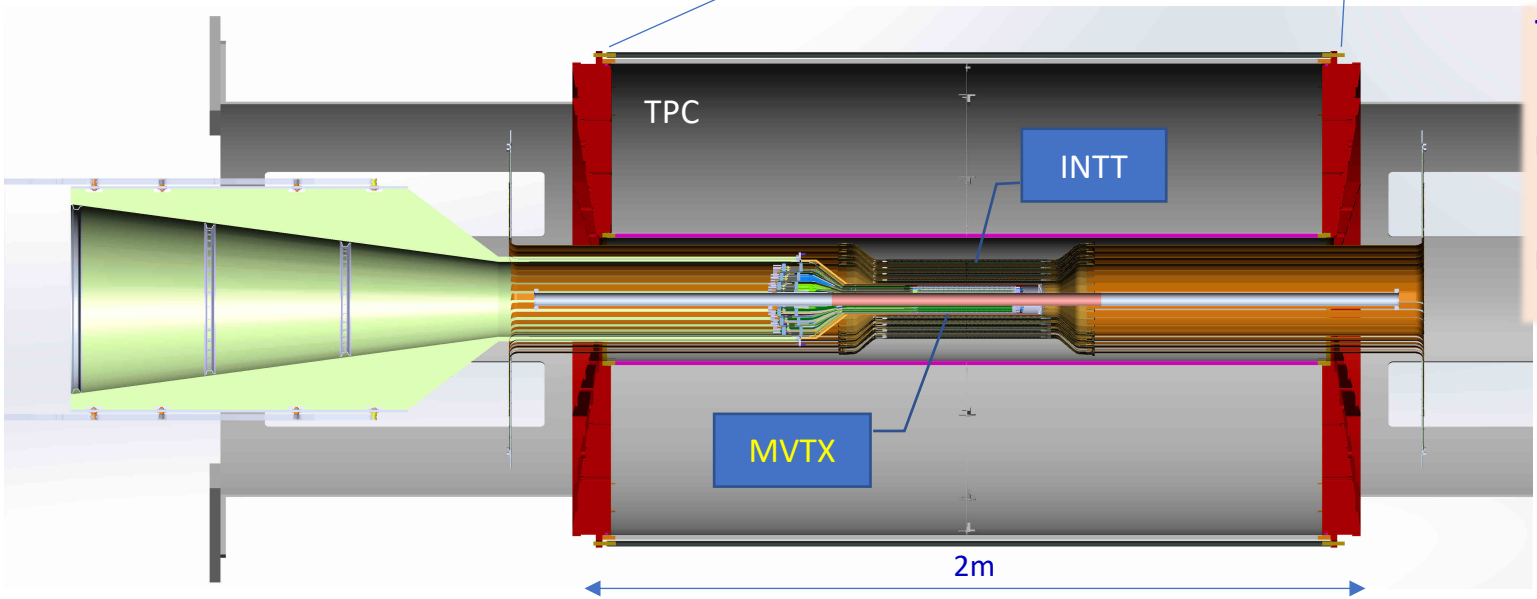
substrate: $N_A \sim 10^{18}$
epitaxial layer: $N_A \sim 10^{13}$
deep p-well: $N_A \sim 10^{16}$

sPHENIX Tracking System

- Excellent Tracking system:
  - TPC: Time Projection Chamber
  - INTT: Intermediate Silicon Strip Tracker
  - MVTX

$$|\eta| < 1, |Z| < 10cm$$





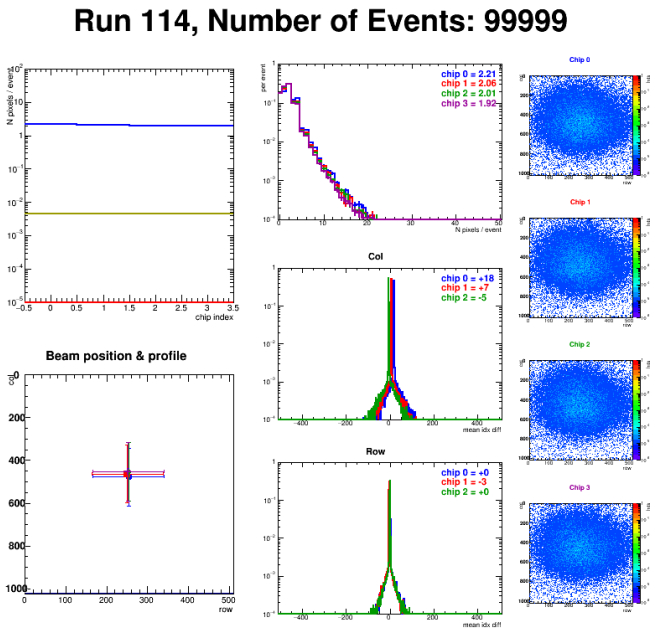
TPC:
R = 20-80cm

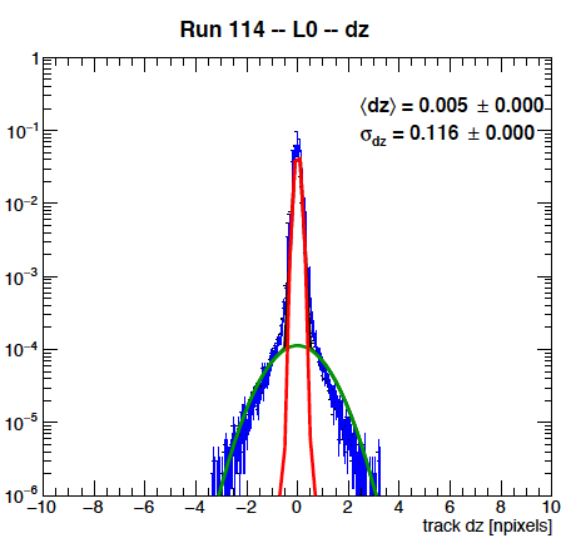
INTT:
R =6,8,10,12cm

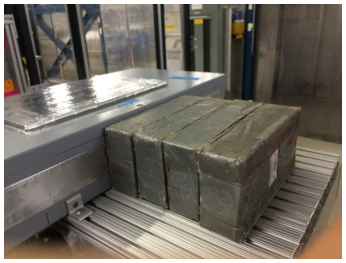
MVTX:
R=2.3, 3.2, 3.9cm

Fermilab Test Beam Summary

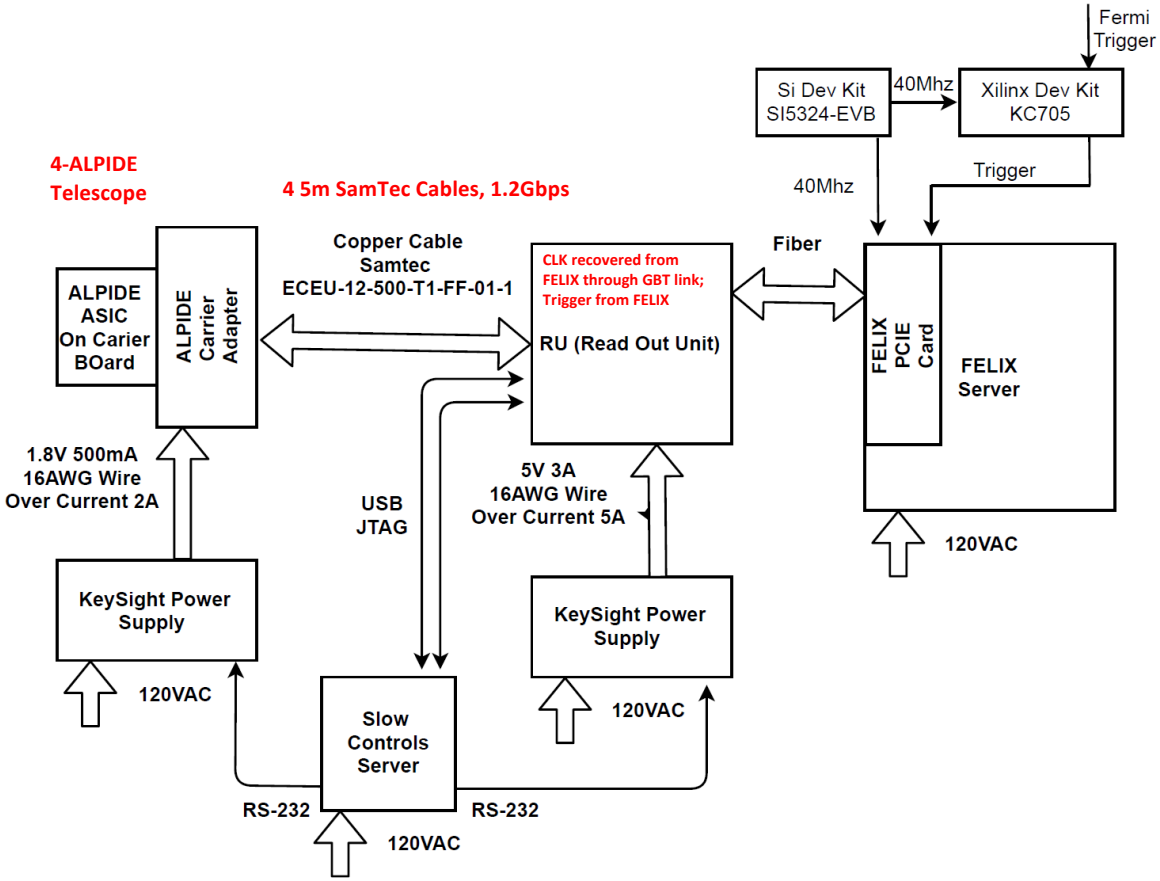
- Successfully operated the full readout chain
  - RU Configured and readout 4 ALPIDEs
  - FELIX successfully integrated into RCDAQ
- Sensor Performance
  - Cluster Size
  - Threshold parameters
  - trigger delay
- High multiplicity events
  - ALPIDE occupancy runs with 10cm lead bricks
- Online Monitoring
  - Hit distribution, relative alignment
- Analysis confirmed telescope performance
  - Hit resolution < 5 um

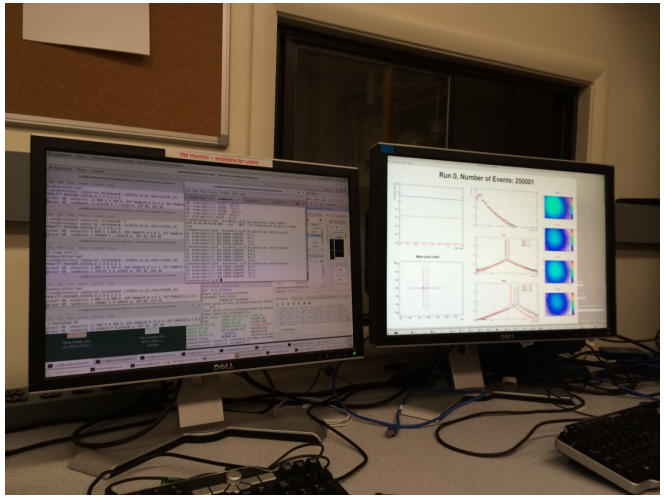




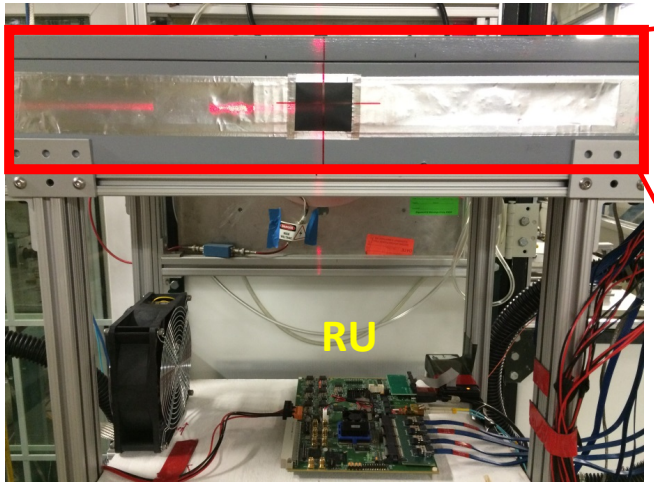


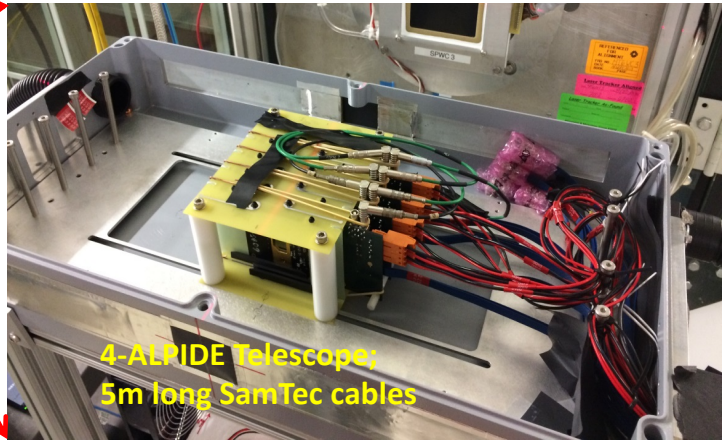
Fermilab Beam Test Block Diagram

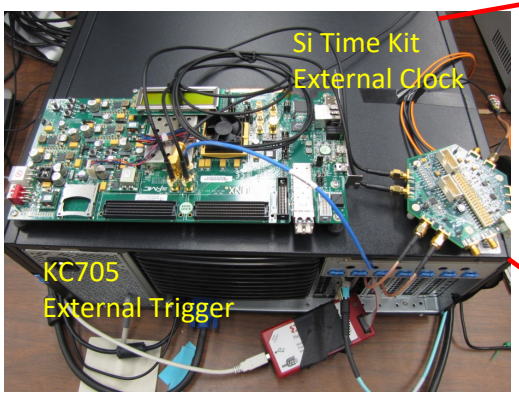


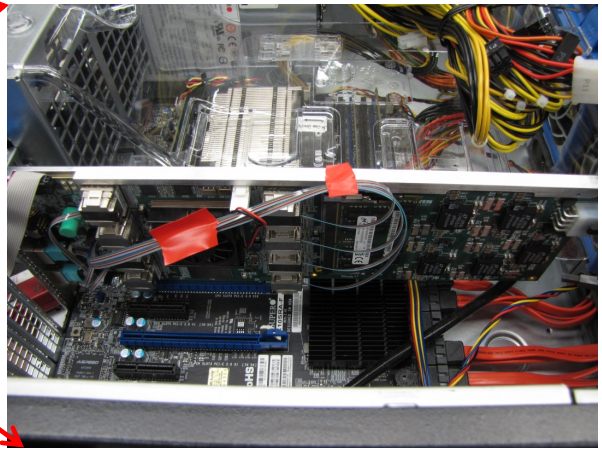


4 Sensor Telescope at Fermilab



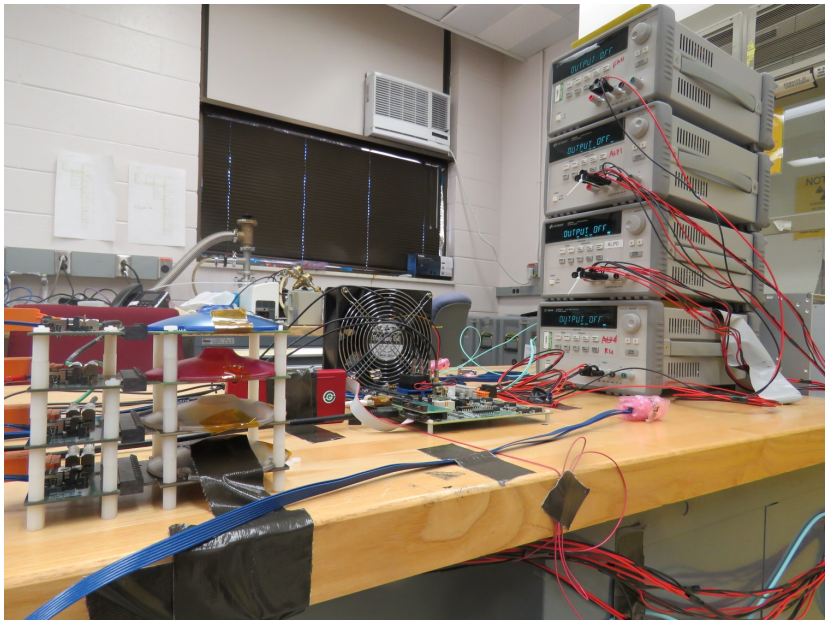




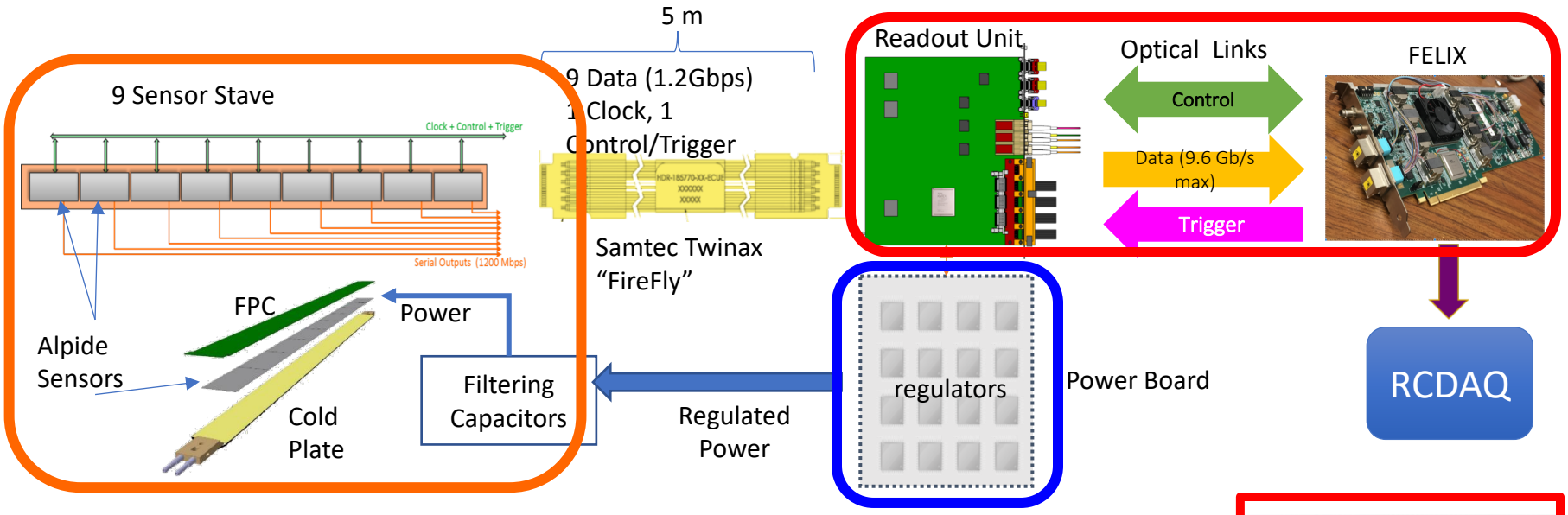


R&D Gameplan

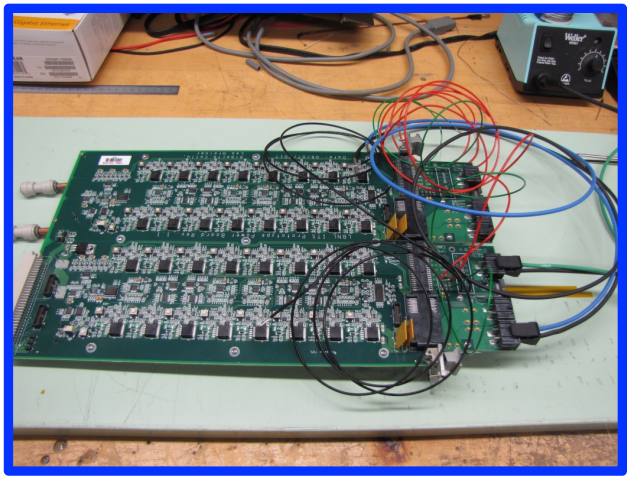
- ALPIDE Characterization
- ALPIDE Triggered & Continuous Modes
- Remote Readout Unit programming (over fiber)
- Readout Unit Radiation Upset (Scrubbing) Firmware
- FELIX programming (over PCIe).
- RCDAQ (sPHENIX DAQ) finalization
- Flex Cable Extension
- System Optimization & Documentation



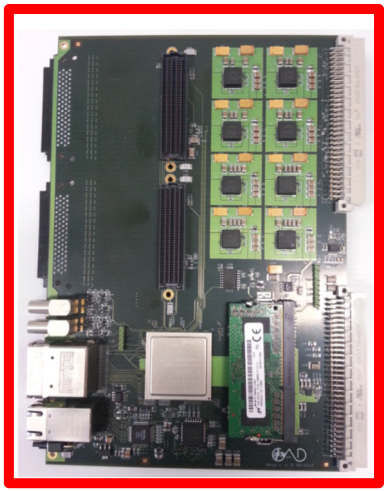
A Test Bench at LANL



One HIC and 5+ individual ALPIDE chips.



Power Board

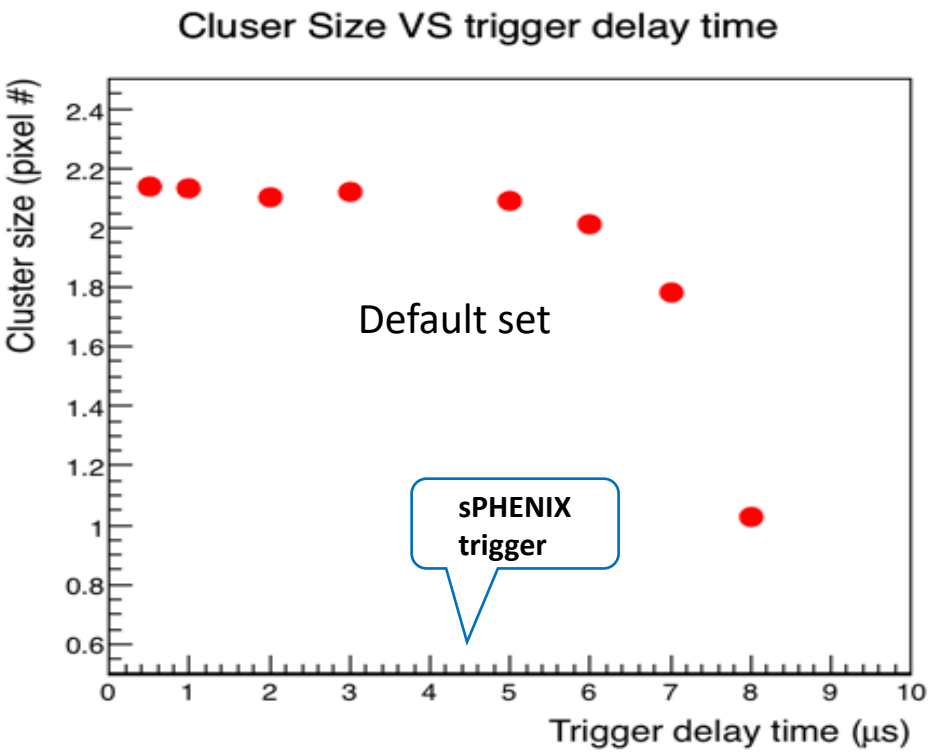


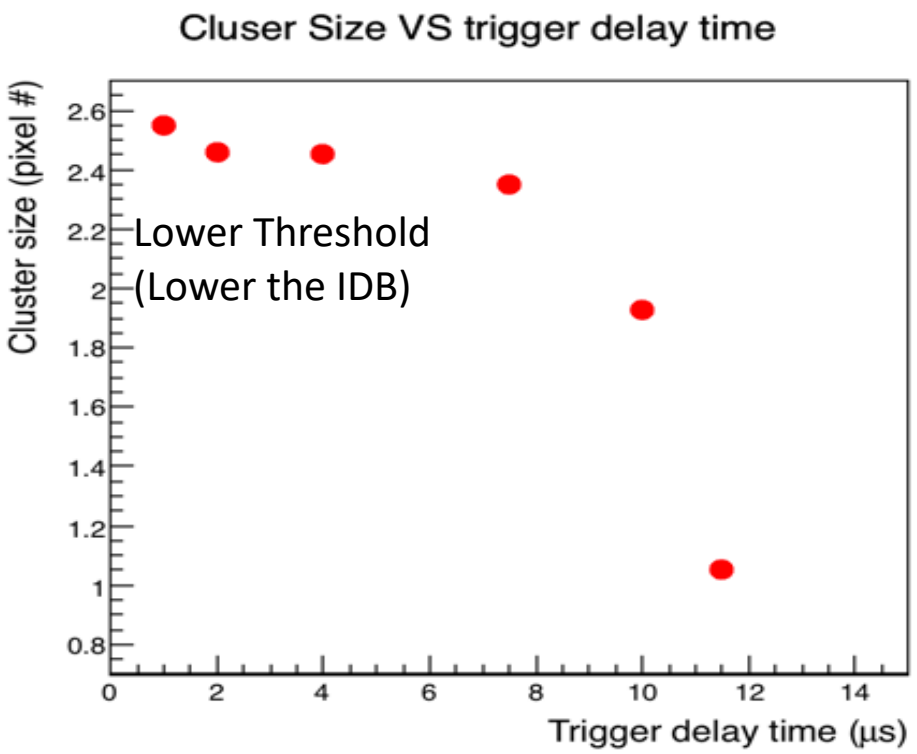
MOSAIC miniDAQ

Trigger Latency and Signal Shaping Time Study

- Lower the OUT_D threshold (IDB) increases the trigger duration time, but also increases the cluster size which might include more background hits.

In the continuous readout mode, "trigger/strobe" can start as early as ~1uS



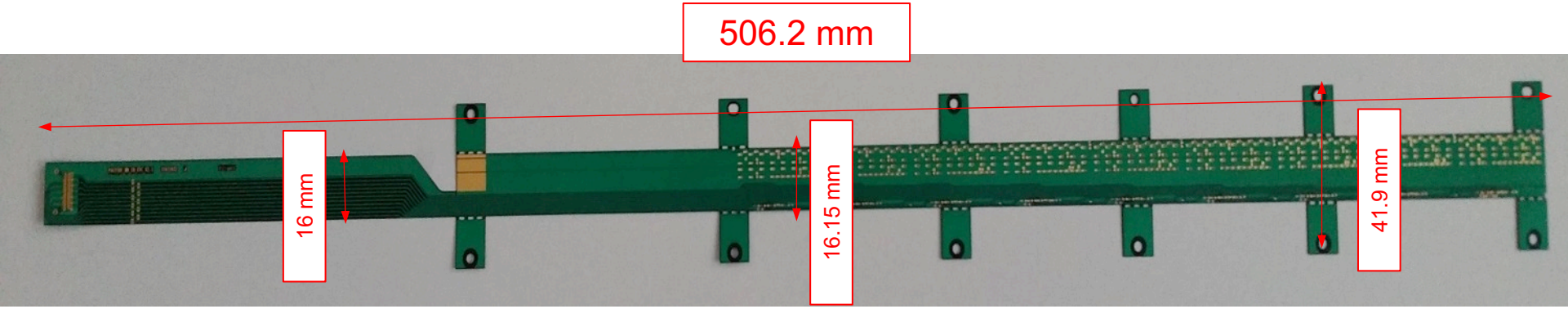


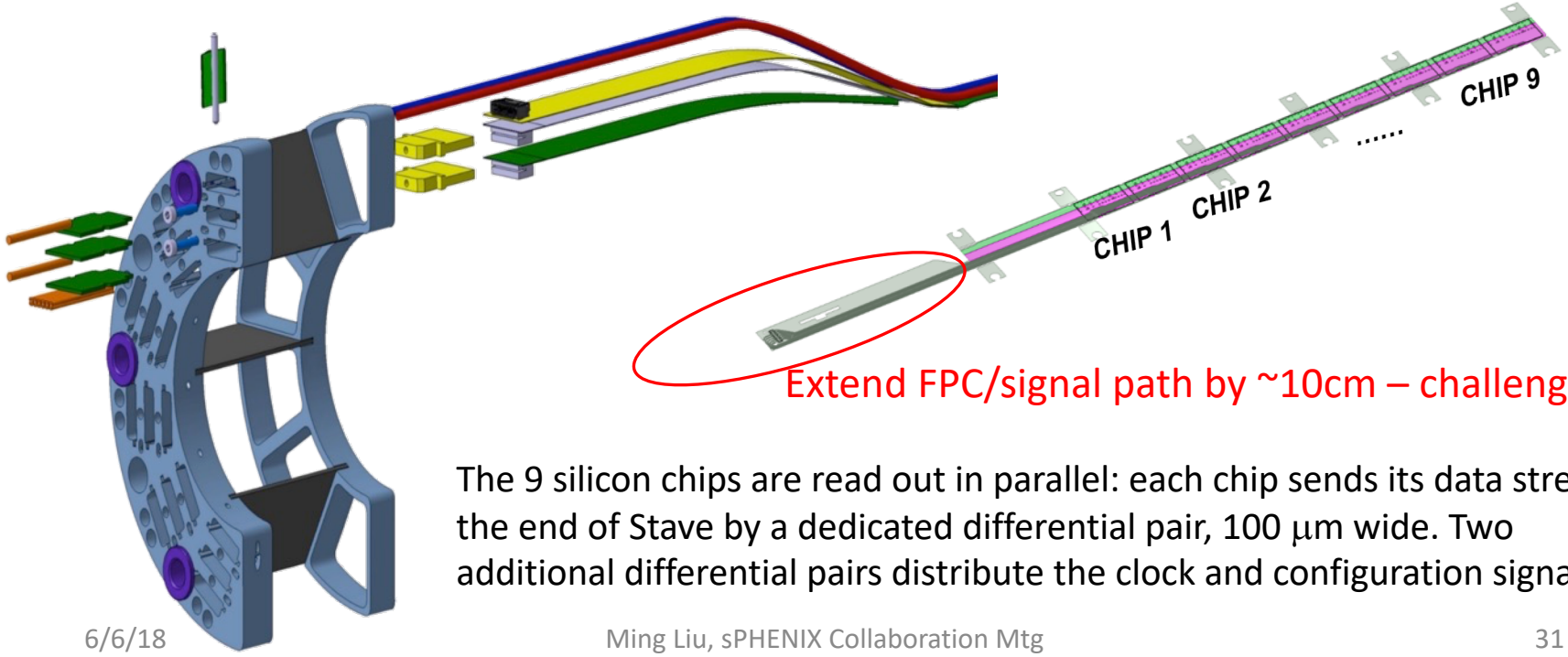
Nice work done by Xuan, Sho and Alex + others

MVTX Flexible Printed Circuit (FPC)

Extend MVTX Service Cables?

Maximum ~60cm for HS signal, TBD through R&D

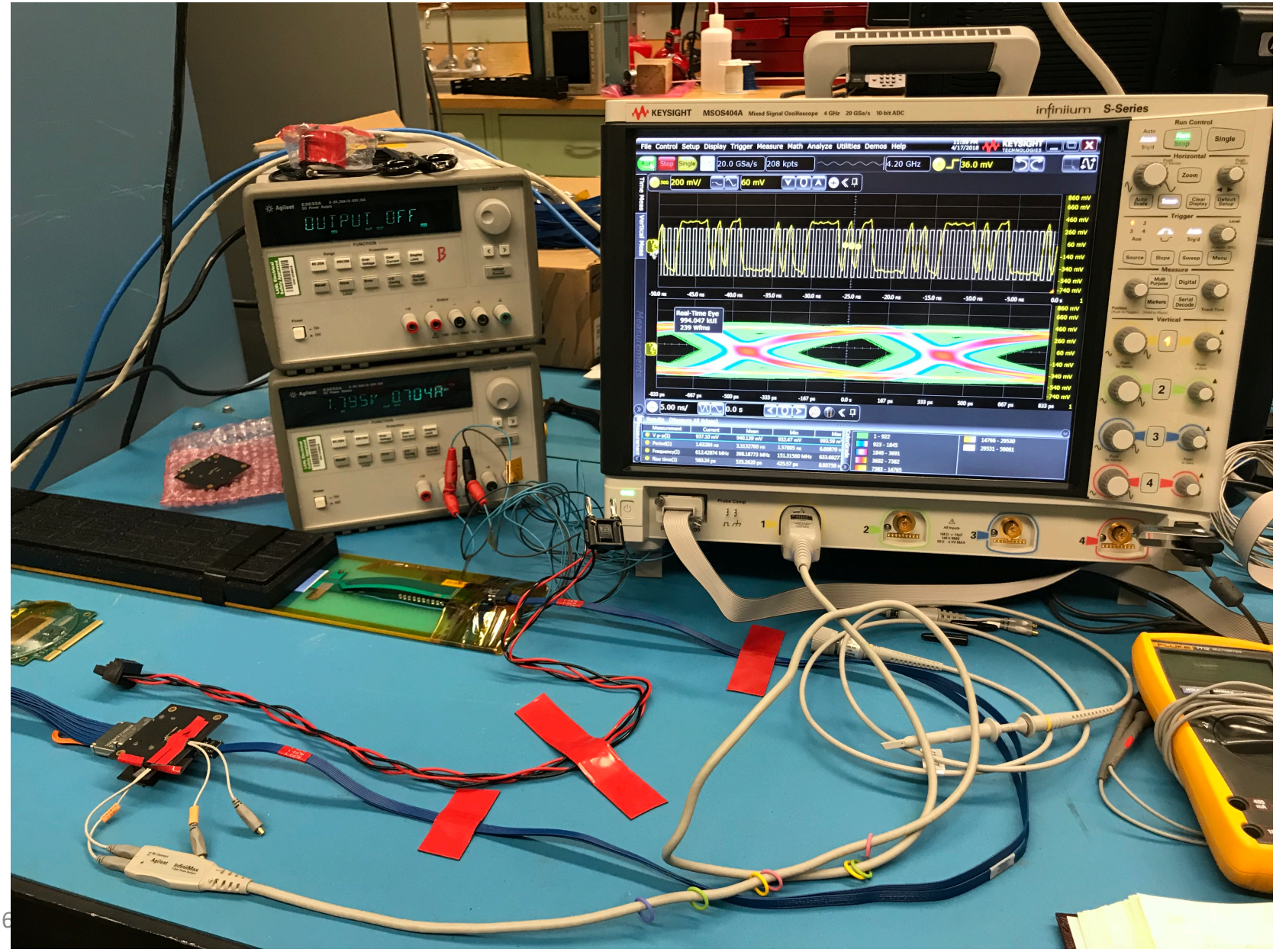




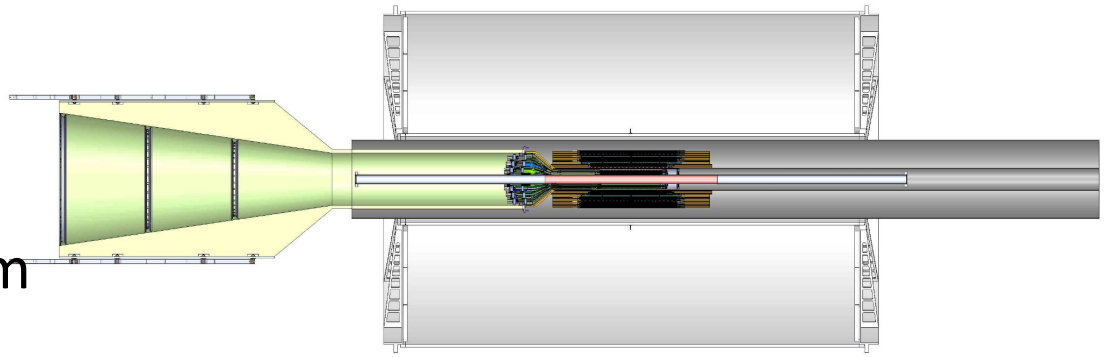
Extend FPC/signal path by ~10cm – challenging!

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.

SamTec Cable and FPC Extension R&D



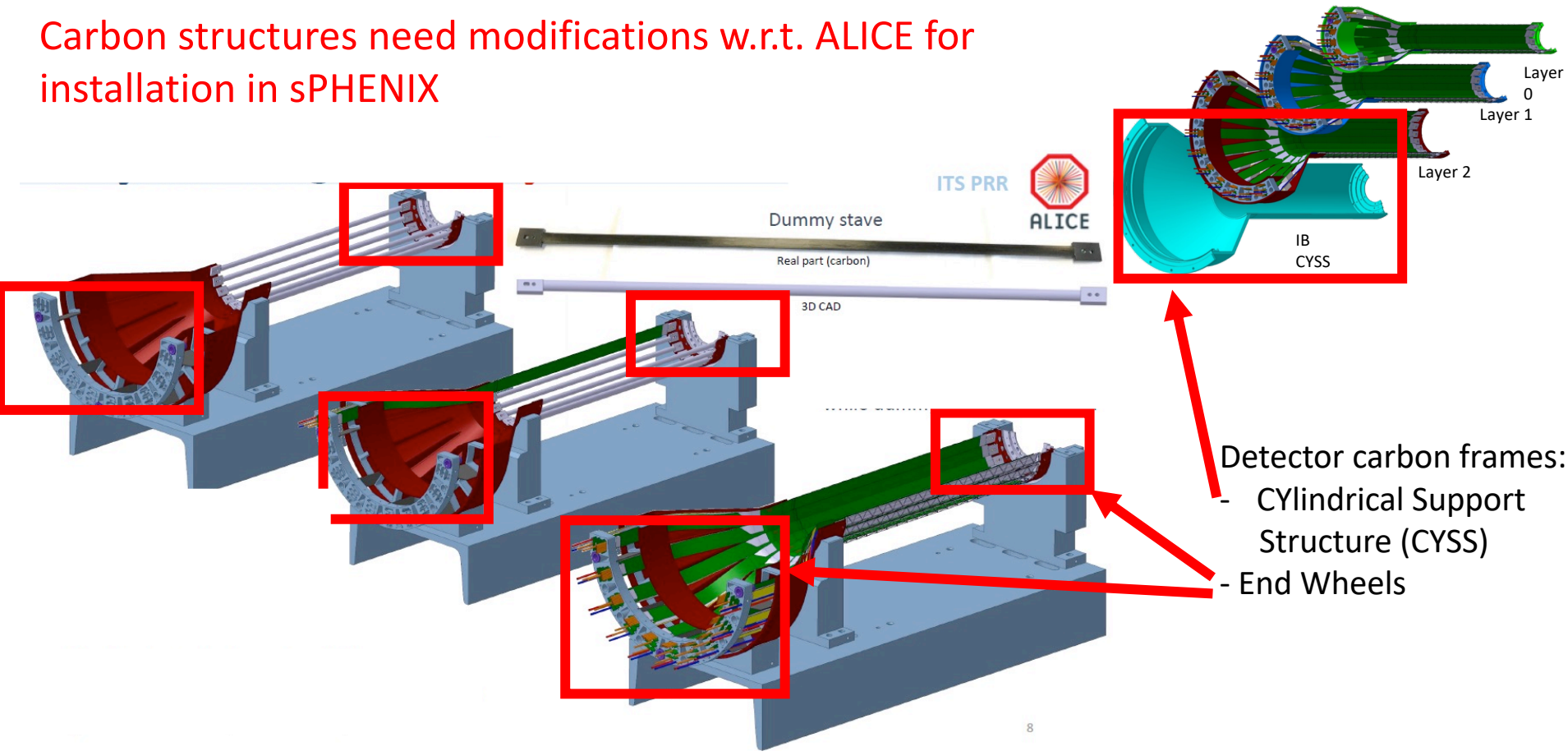
To Do List



- FPC extension
  - Power extension, ~50cm
- SamTec cable length vs signal quality
  - 5~7m
  - RU location, MVTX electrical system integration
- Carbon structure and connector design
  - FPC HS signal connectors
  - FPC power extension connectors
  - MVT Service barrel and mechanical system integration
  - Installation procedure

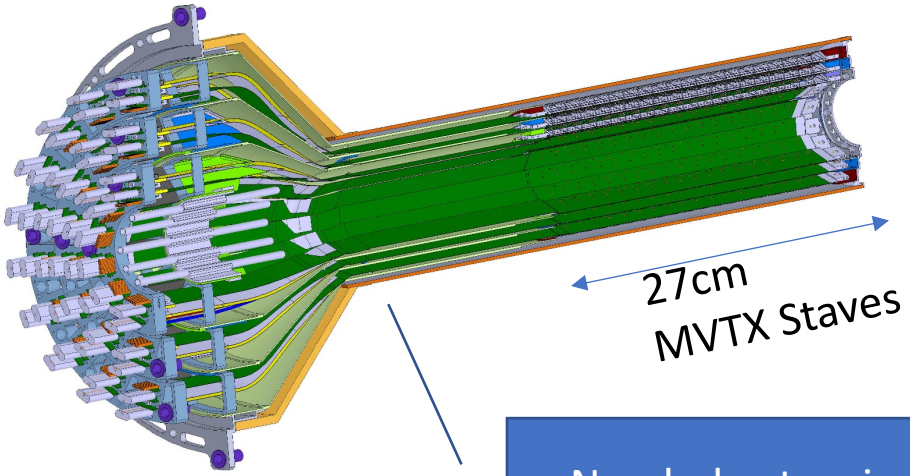
MVTX Carbon Structures

Carbon structures need modifications w.r.t. ALICE for installation in sPHENIX

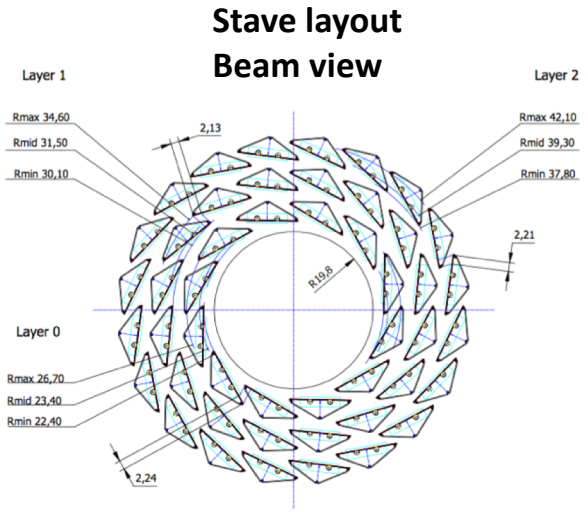


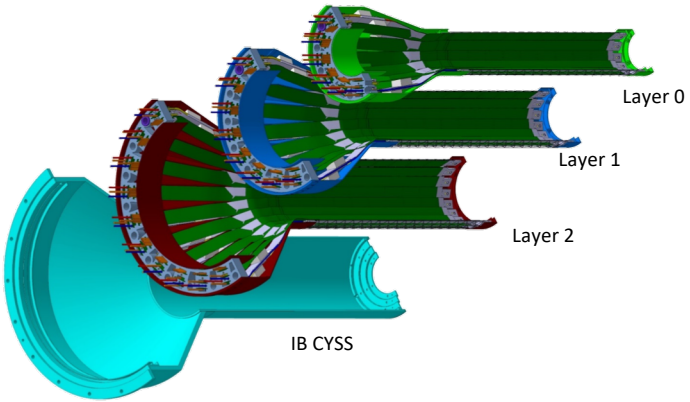
MVTX Mechanical Conceptual Design

- View of MVTX half detector assembly with extended central barrel



Needed extension for sPHENIX INTT integration, ~6cm possible





INTT Support Structure from Dan Cacace, 4/27/2018