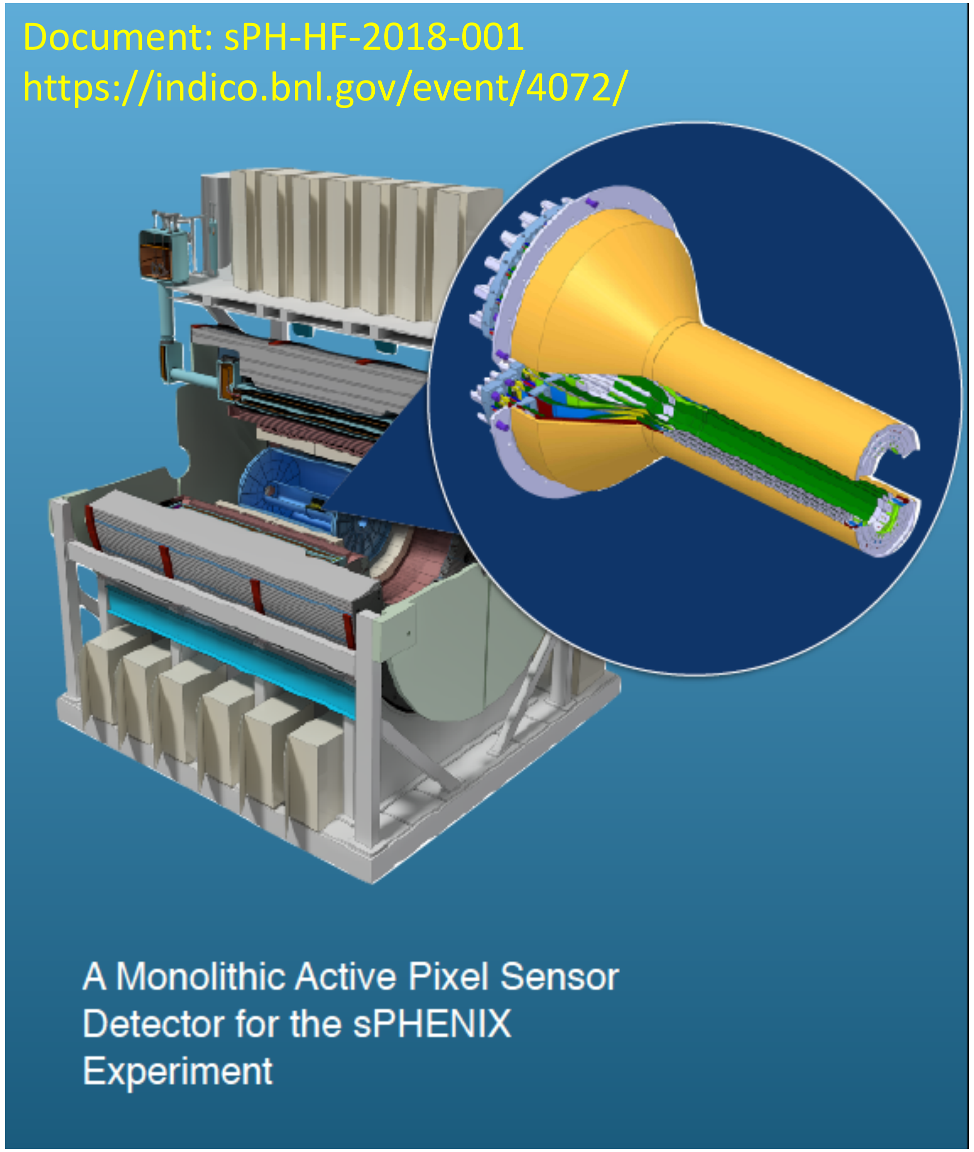
MVTX Overview

Ming Liu

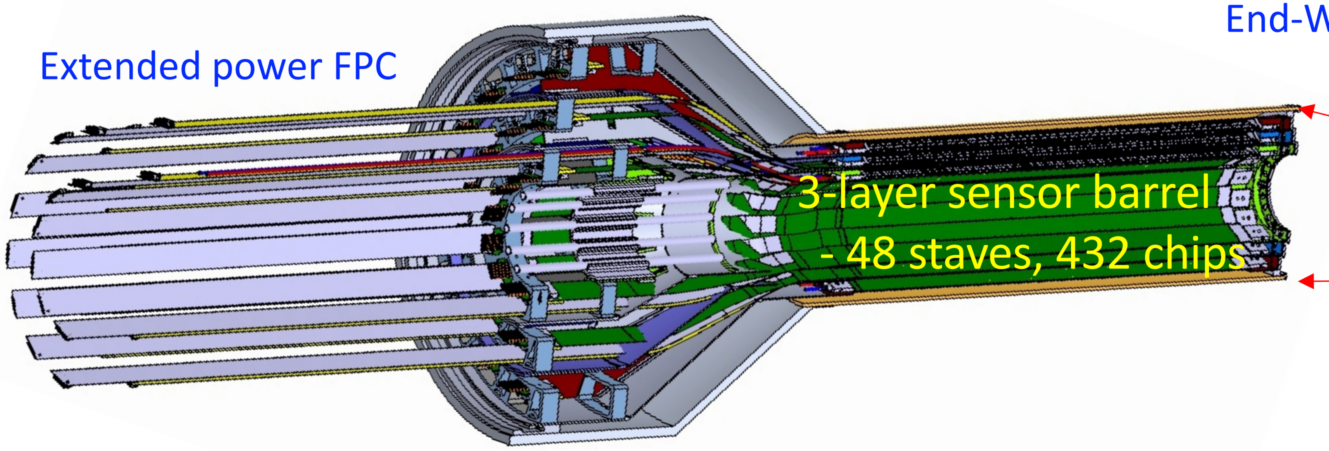
LANL

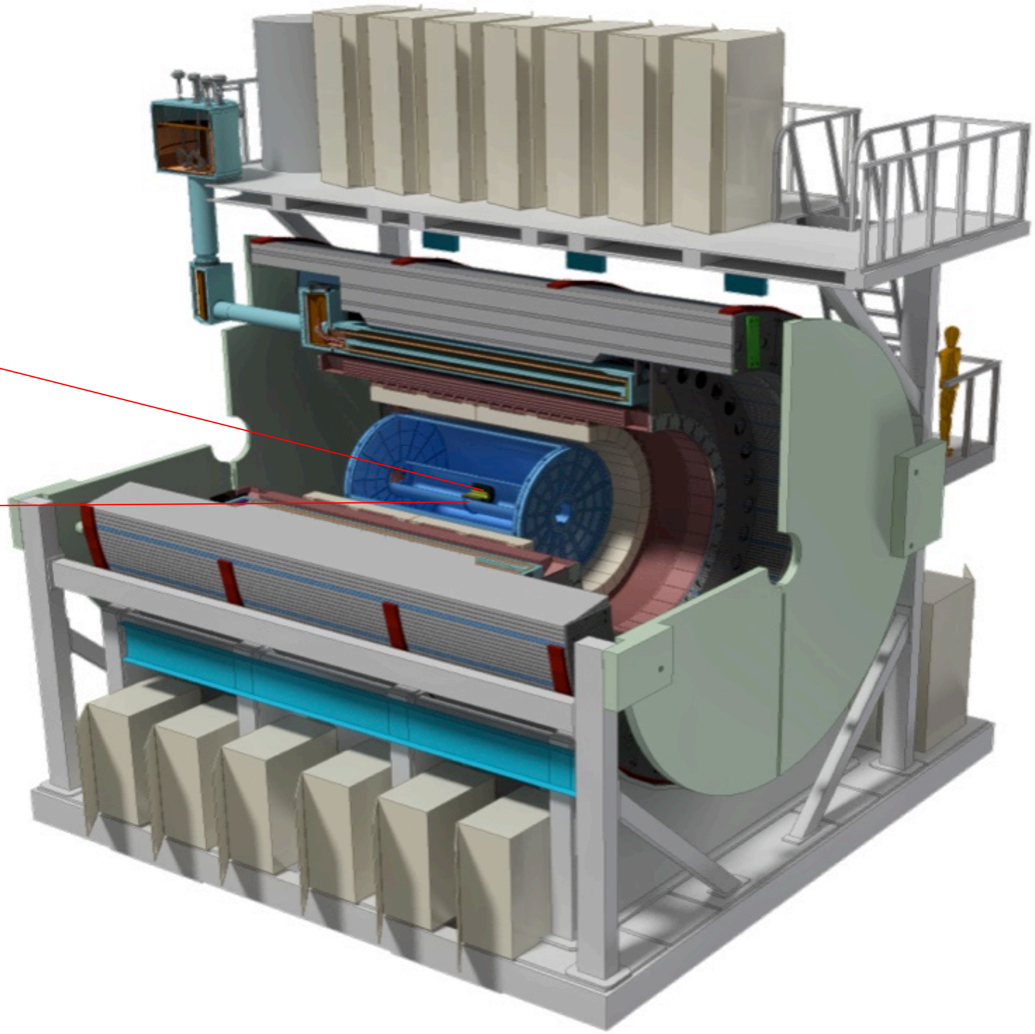
sPHENIX Collaboration Meeting

July 8-9, 2019, Lehigh University, PA



MVTX Detector – Modified from ALICE/ITS Design





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 - WBS3.2

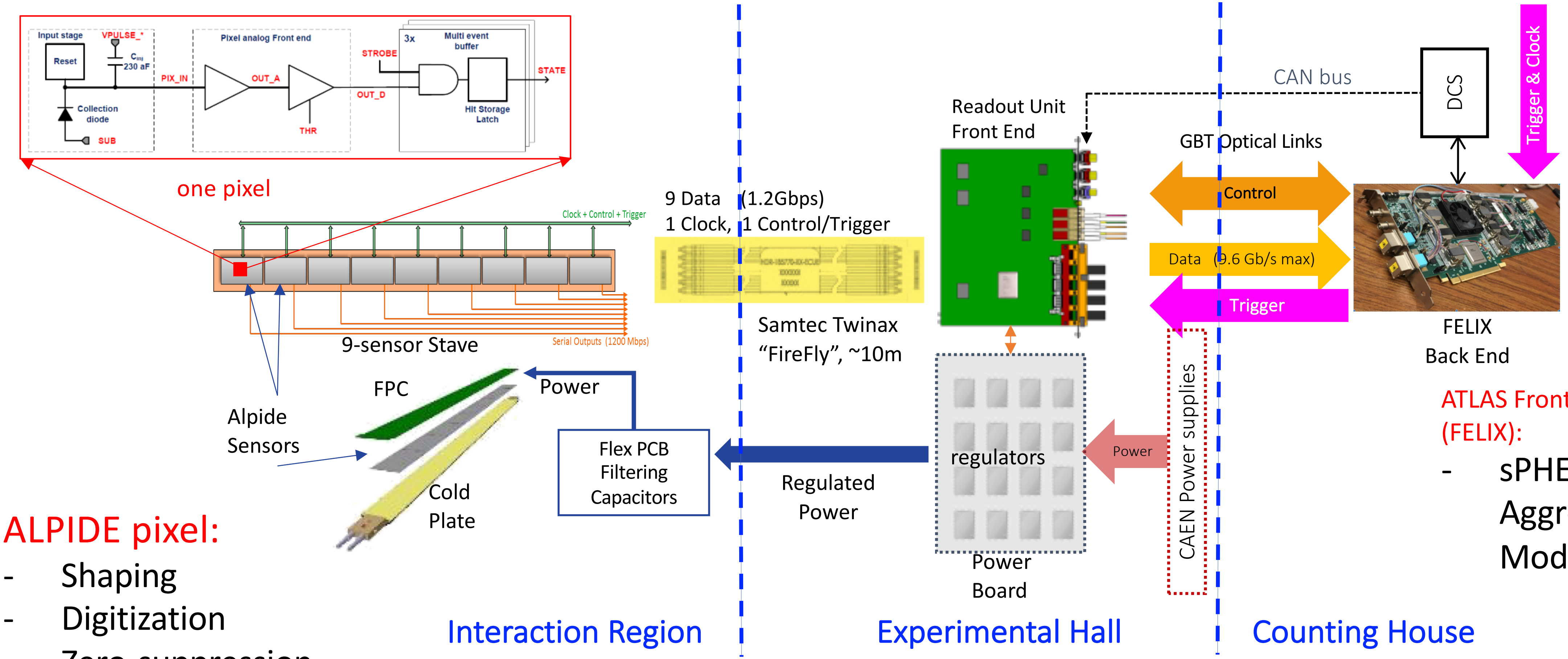
- MVTX sensor & Electronics
  - Readout Integration
    - Frontend: ALICE/ITS RU
    - Backend: ATLAS FELIX
  - Assembly & production @US: ~$5M
    - QA & assembly
      - RU boards @UT-A
      - Half detectors @LBNL
      - FELIX boards @LANL/BNL, 6+spares(2)
    - Ancillary systems - "adopt" ALICE ITS system
      - Power, slow control & monitoring etc.

Production @CERN: $1.36M, a separate BNL project

- 84 ALICE/ITS-IB (modified) staves from CERN
  Acceptance test @LBNL, 48+spares(2-inner layers+)
- 60 ALICE/ITS-RU from CERN
  Acceptance test @UT-Austin, 48+spares(12)

- Mechanical system
  - Modify ALICE/ITS mechanical structures
    - End Wheels
    - Cylindrical structure shells
    - Service half barrels
  - Mechanical system integration,
    - Design & simulations, MIT/LANL
    - Composite structure production, LBNL
    - Non-composite structure, MIT
    - Installation tooling etc., BNL/LANL/MIT/LBNL
  - Adopt ALICE cooling plant design
    - Modifications to fit sPHENIX, MIT/BNL

MVTX Readout, Power and Controls



- Slow control Mike's talk

ATLAS Front-End Link eXchange (FELIX):

- sPHENIX Data Aggregation Module(DAM)

ALPIDE pixel:

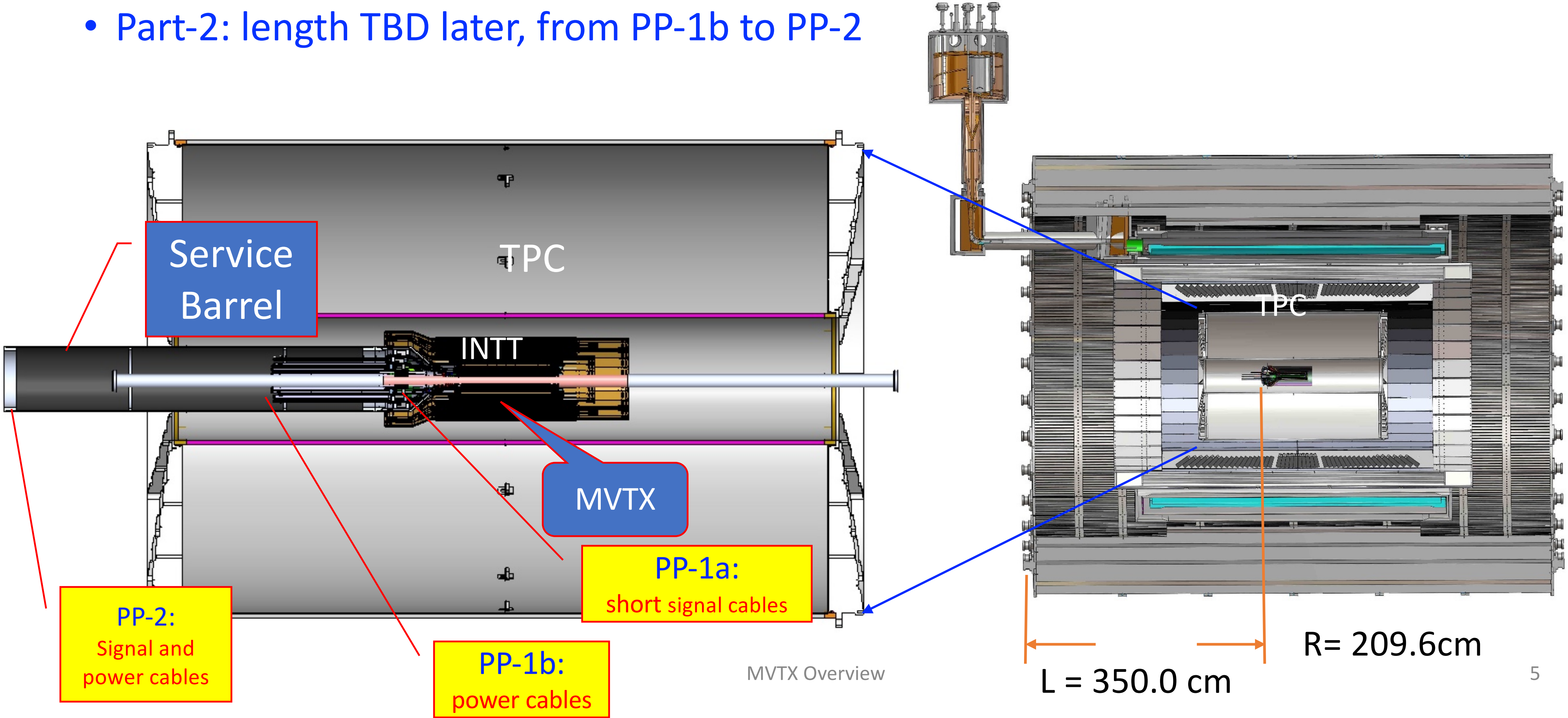
- Shaping
- Digitization
- Zero-suppression
- 3x buffer

MVTX Detector Electronics consists of three parts

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

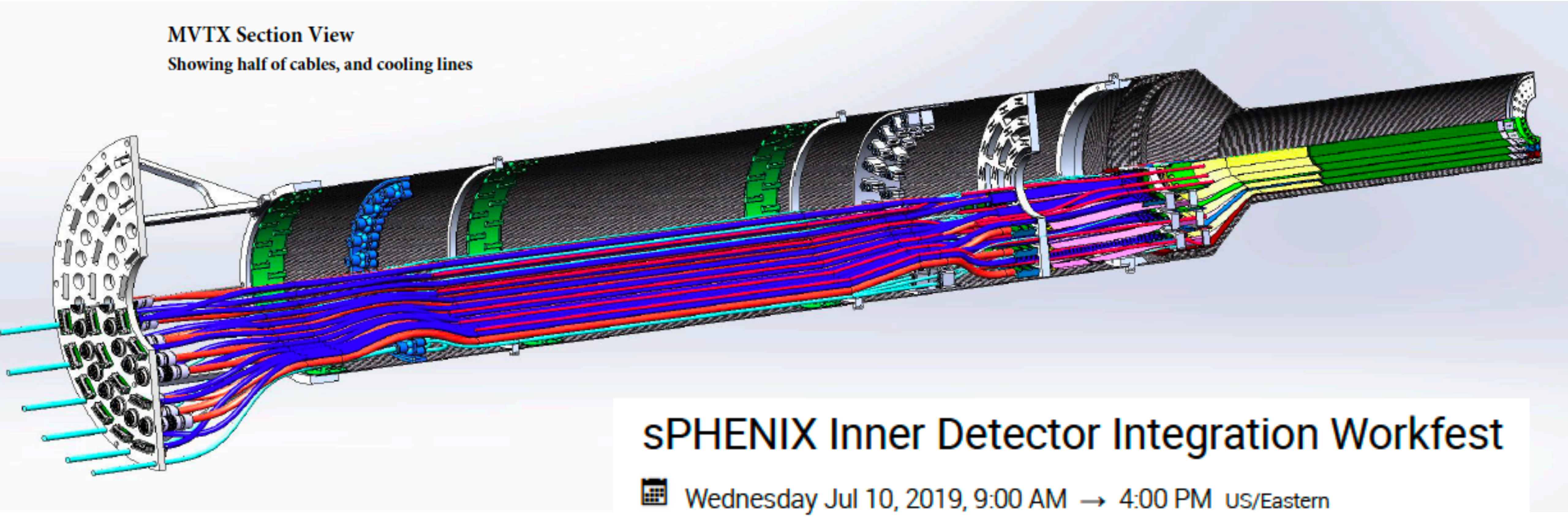
MVTX Global Mechanical System Integration

- MVTX system preliminary design, with two parts:
  - Part-1: from MVTX to PP-1b, all power PCB, 40cm
  - Part-2: length TBD later, from PP-1b to PP-2



Preliminary Mechanical Design Completed

Ross' talk



https://indico.bnl.gov/event/6377/

- MVTX, INTT, TPC …

Project Status Update

- Confirmed long SamTec readout cables recently – last key integration R&D
  - 11.4m long cables, > 10m desired length
- MVTX mechanical design: excellent progress
  - Asked for quotes from outside companies based on preliminary designs
  - sPHENIX integration workfest scheduled 7/10 @BNL, MVTX/INTT/TPC…
- Release of early R&D fund in progress
  - MVTX mechanical engineering design, MIT/LANL
  - Preparation for Stave and RU acceptance test, LBNL, UT-Austin
- MVTX Cost & Schedule Review – we are ready for full production
  - July 29-30 @BNL
  - WBS, PMP, Risk Registry, P6 being updated

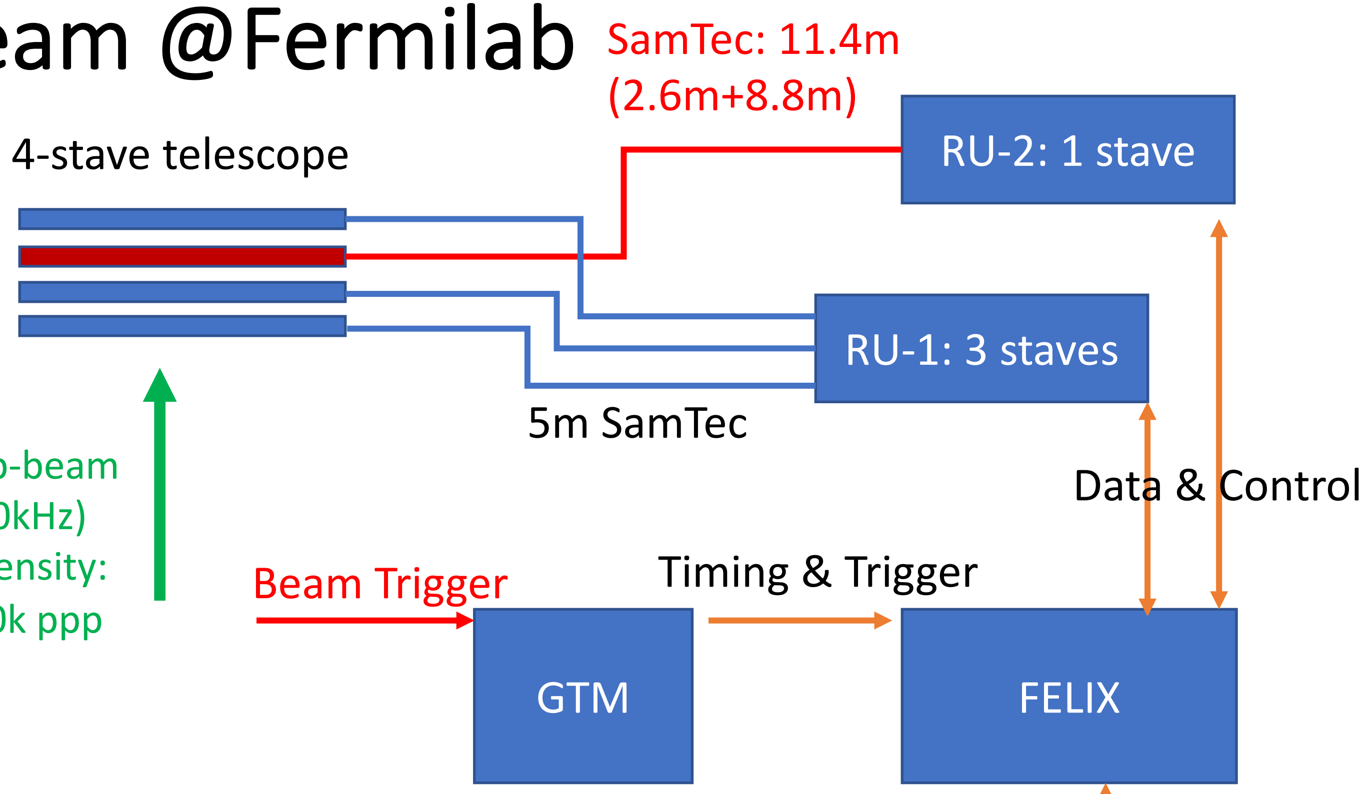
Stave and RU production at CERN

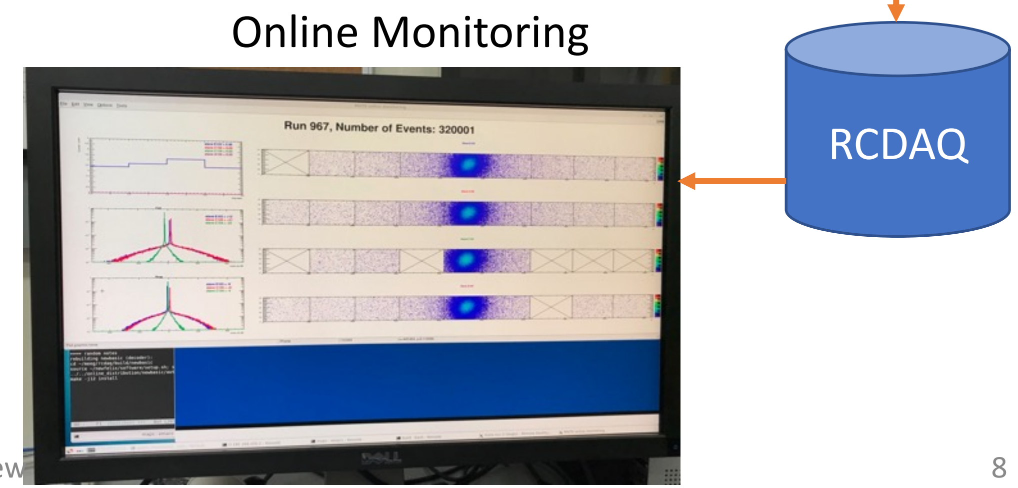
- DOE Fund arrived at UTK/US-ALICE
- Procurement in progress
  - CERN is ready to proceed with stave production
  - 60 MVTX RUs delivered to CERN
- Power mezzanine and transition boards produced at UT-A

Very Successful Test Beam @Fermilab

5/20-25, 6/17-22, 2019

- 4 staves
- 2 RUv1.1
- 1 PU
- 1 FELIX Server + RCDAQ
- sPHENIX GTM
- 11.4m Custom SamTec Cable
- Negative pressured cooling for staves



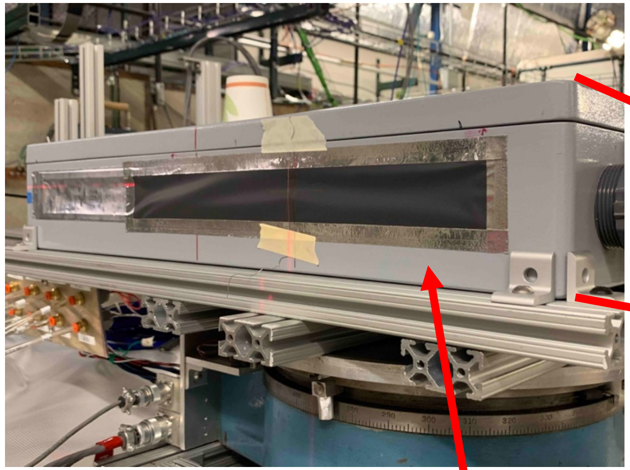


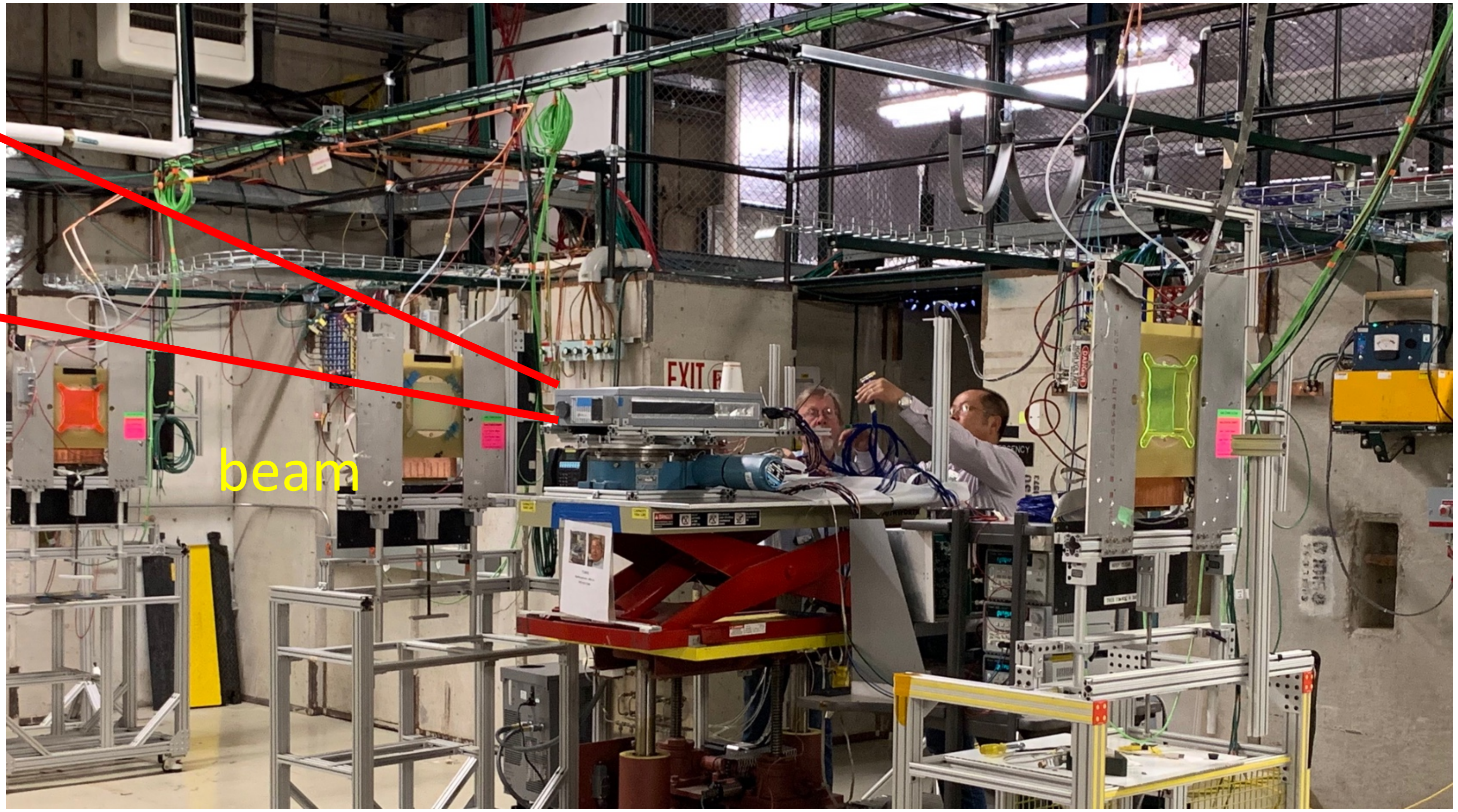
A full system with final sensor/readout* hardware:

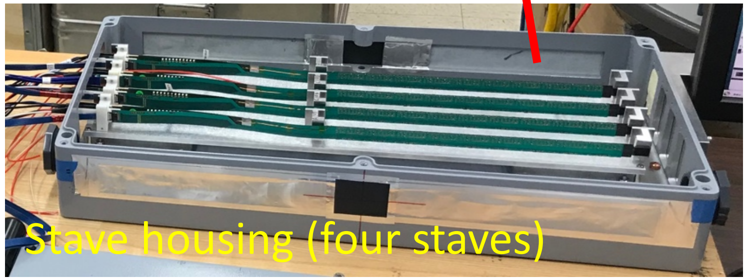
- Multi-Stave + Multi-RU -> FELIX readout demonstrated
- sPHENIX GTM integrated
- Long readout SamTec cable certified
- Cooling system demonstrated

* RUv1.1 identical to the final RUv2 electrically

2019 MVTX Test Setup





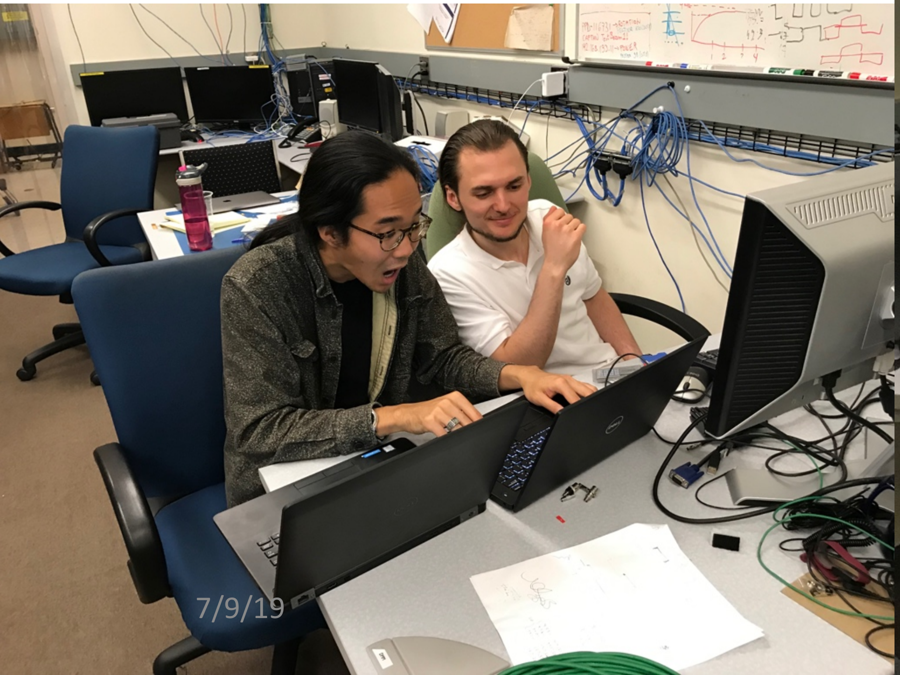


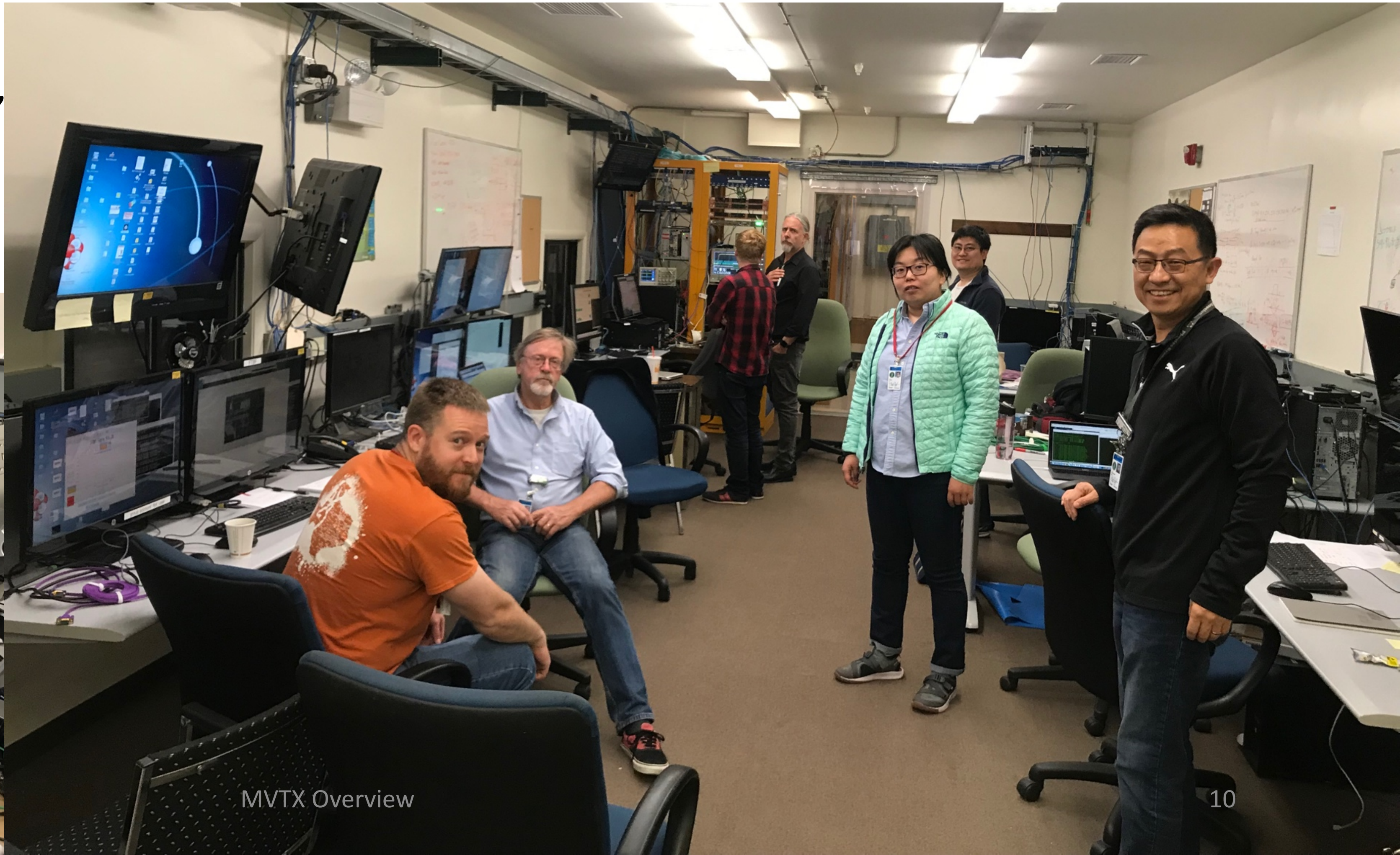
Stave housing sits on a motion table which can be moved in (x, y) plane perpendicular to the nominal beam direction. It can also be rotated (+40, -40) degrees (see photo on right). Operation was done at counting house.

The Team @Fermilab

Data taking shift in the evenings: 7PM – 7AM
Beam: every other Monday –Friday 8:00AM – 8AM

Matt, Hubert, Cameron, Gerd, Zongze,
Xuan, Xiaochun, photo by Ming
Sho, AlexT
Not shown: Sanghoon, Yasser, Martin, Walt,
Abel. Chris …



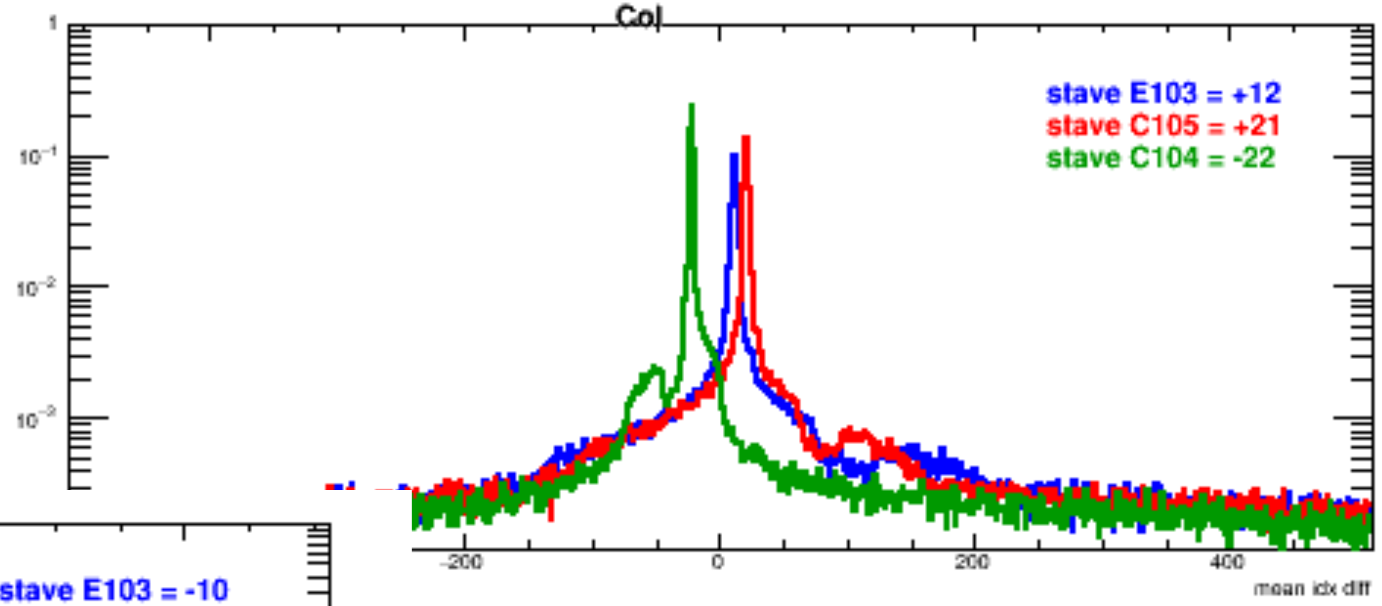


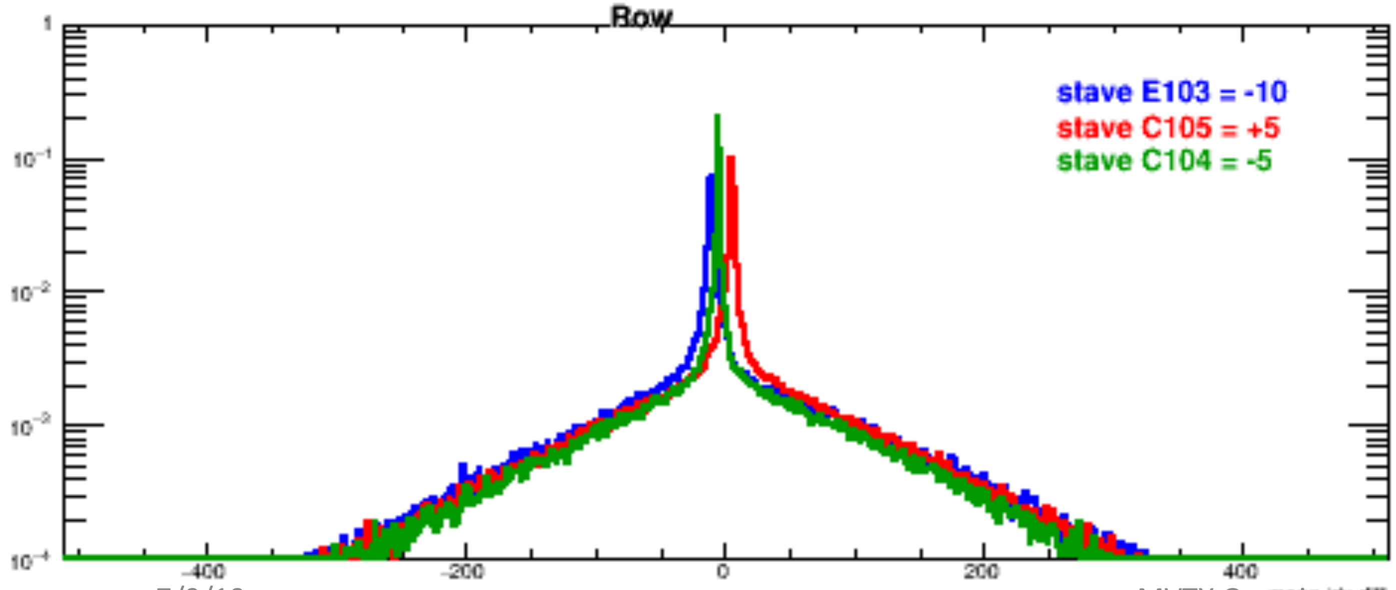
Detector Misalignment & Hit Spatial Resolution

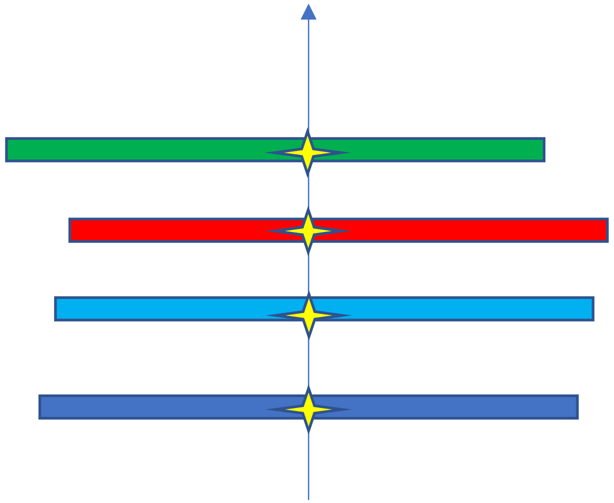
Typically staves offset by,
Horizontally: 20 x 30um = 600 um
Vertically: 5 x 30 um = 150 um

Hit spatial resolution:

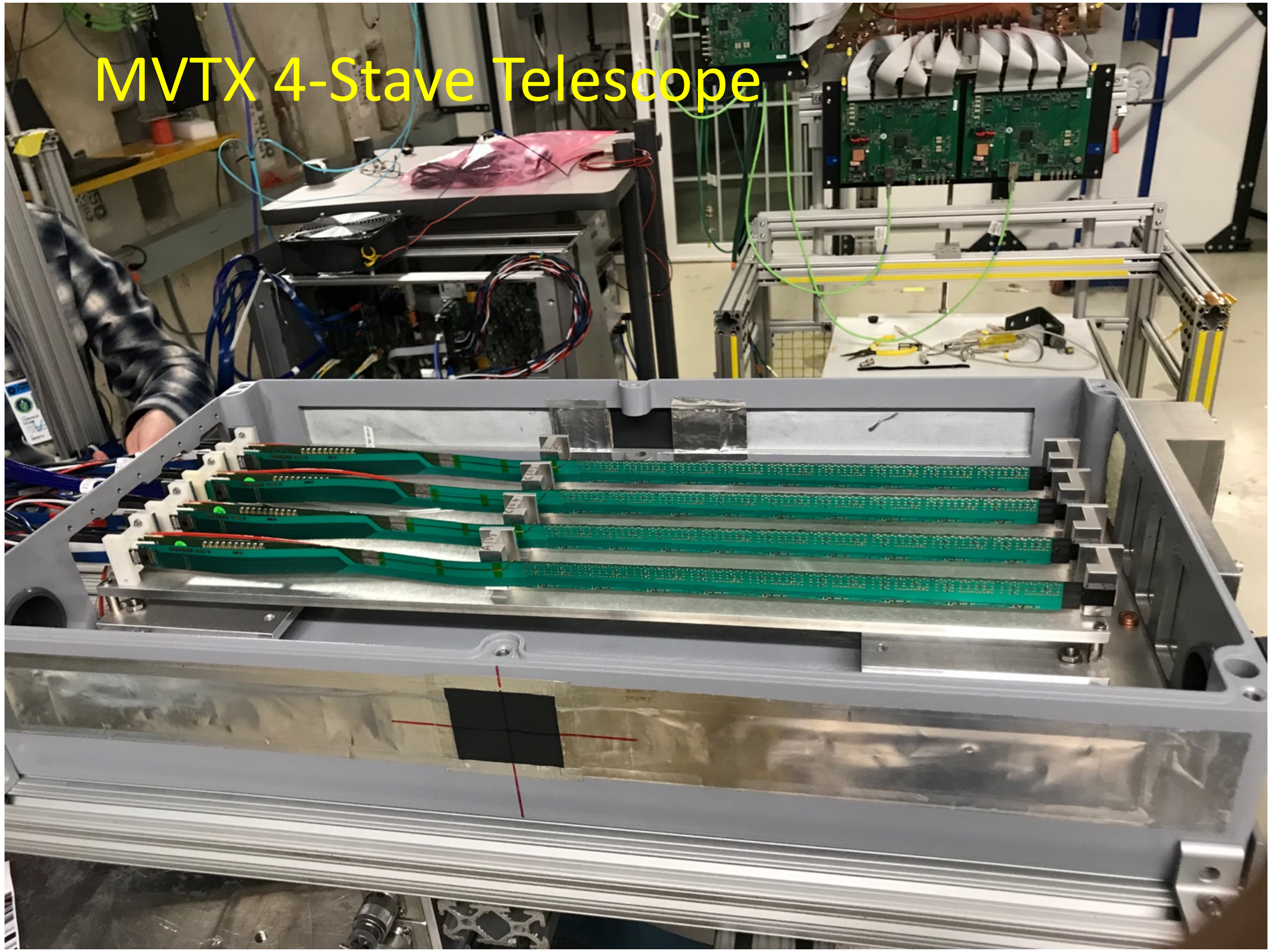
peak_sigma_core = 0.55 (pixel size) =15 um
Chip spatial resolution = 15/sqrt(2) = 11 um



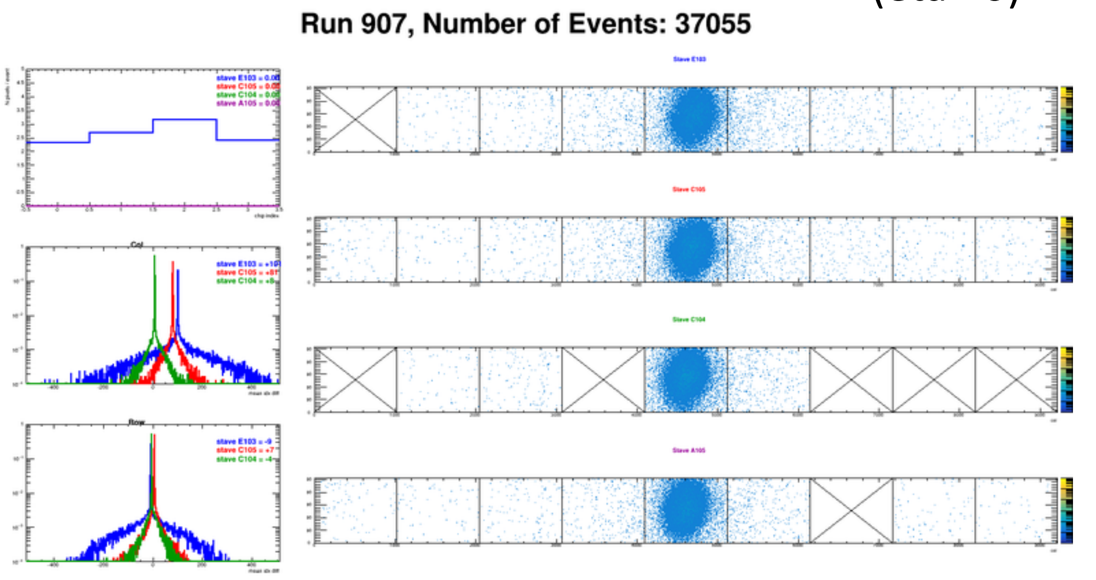




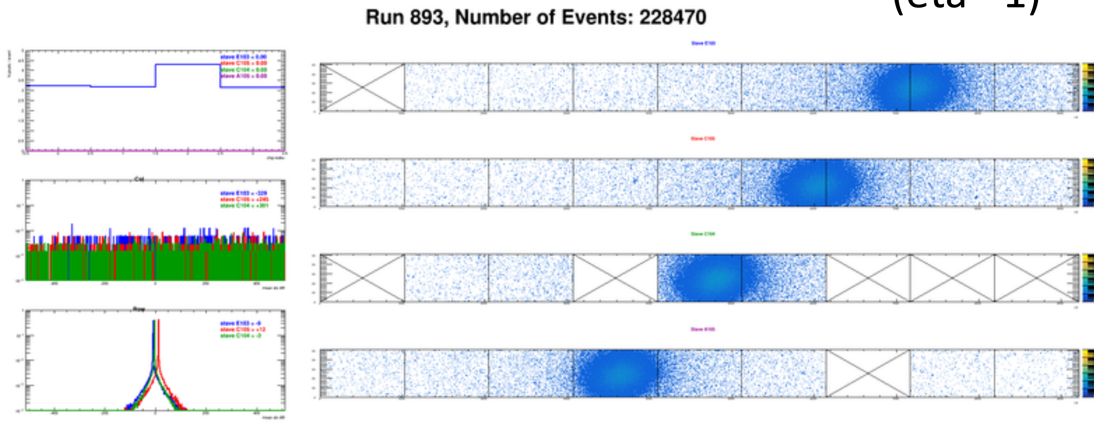
Offline analysis in progress: all TB data in RCF
https://wiki.bnl.gov/sPHENIX/index.php/MAPS-based_Vertex_Detector_(MVTX)



Beam angle: 0
(eta ~0)

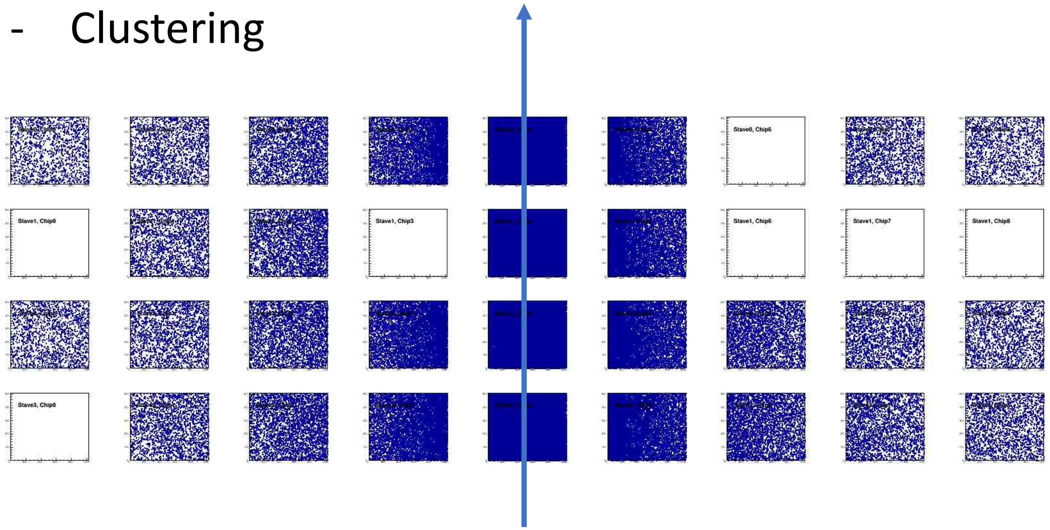


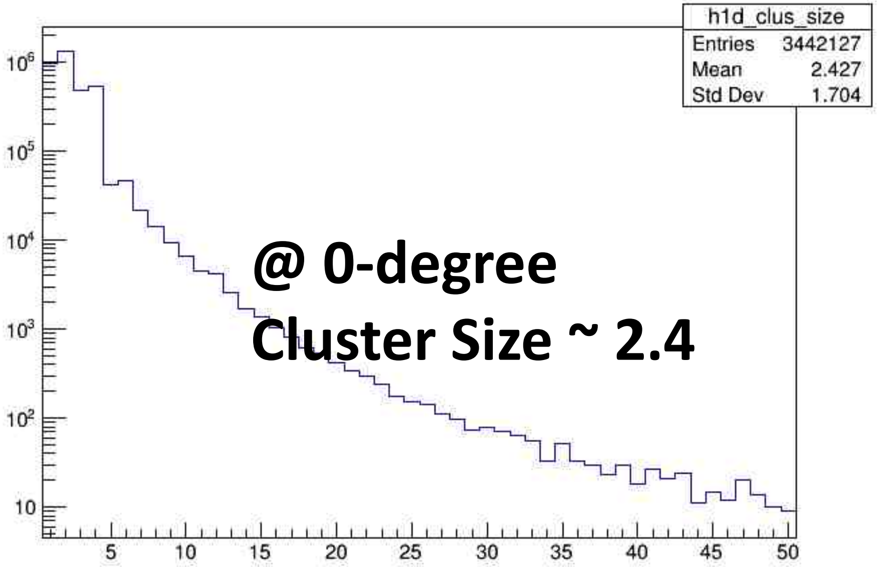
Beam angle: 40
(eta ~1)

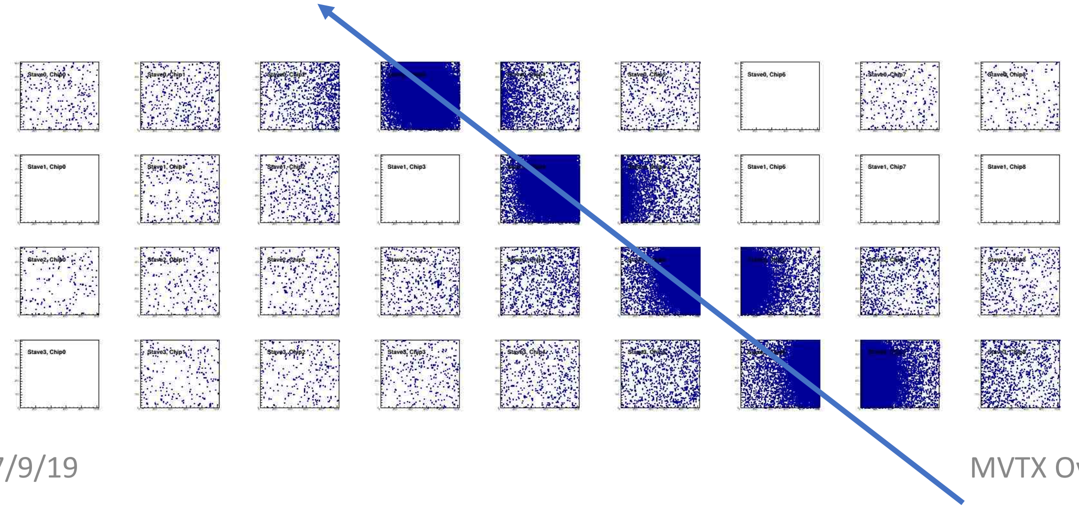


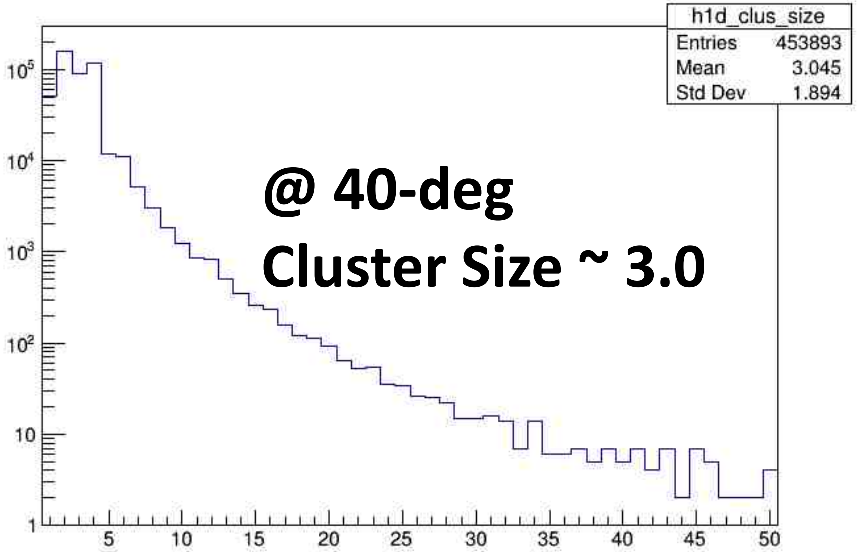
Offline Analysis: Cluster size vs Angle

To calibrate MC simulations and tracking
- Stave geometry, alignment
- Clustering



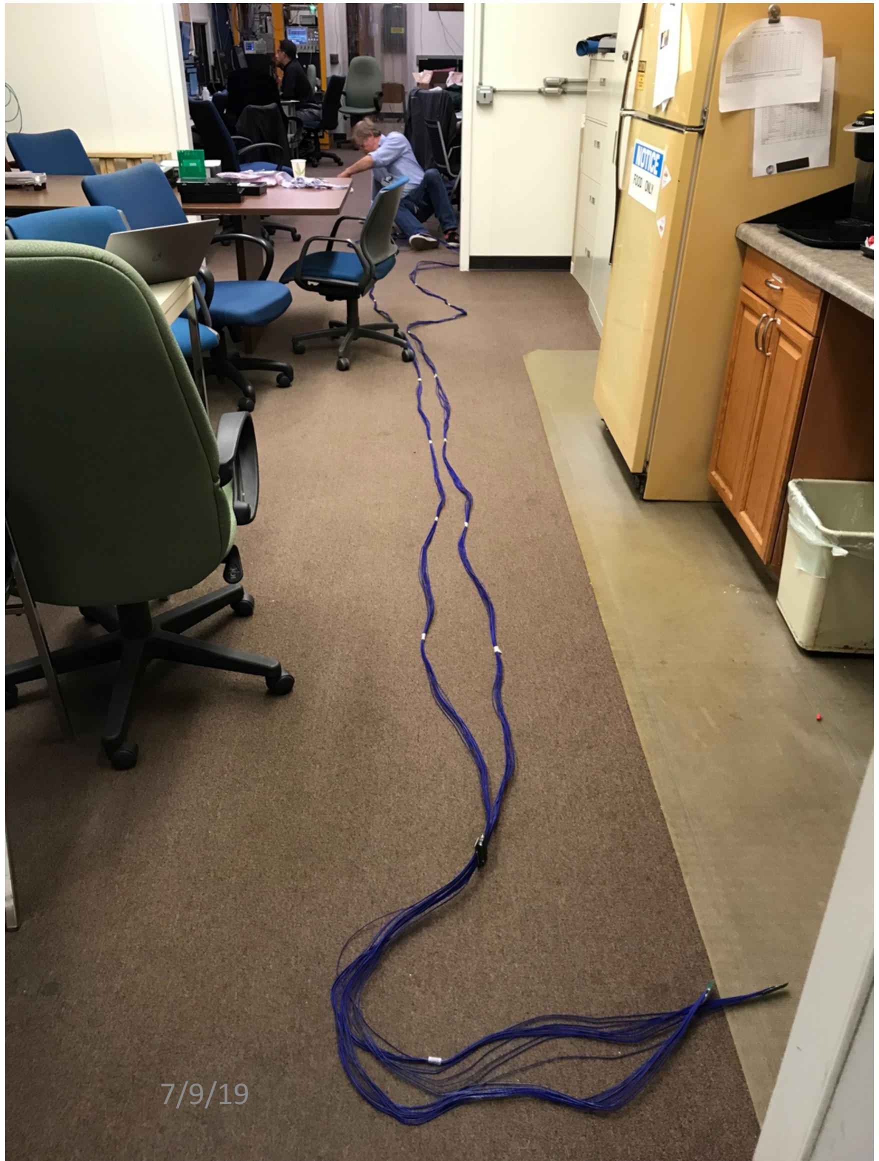




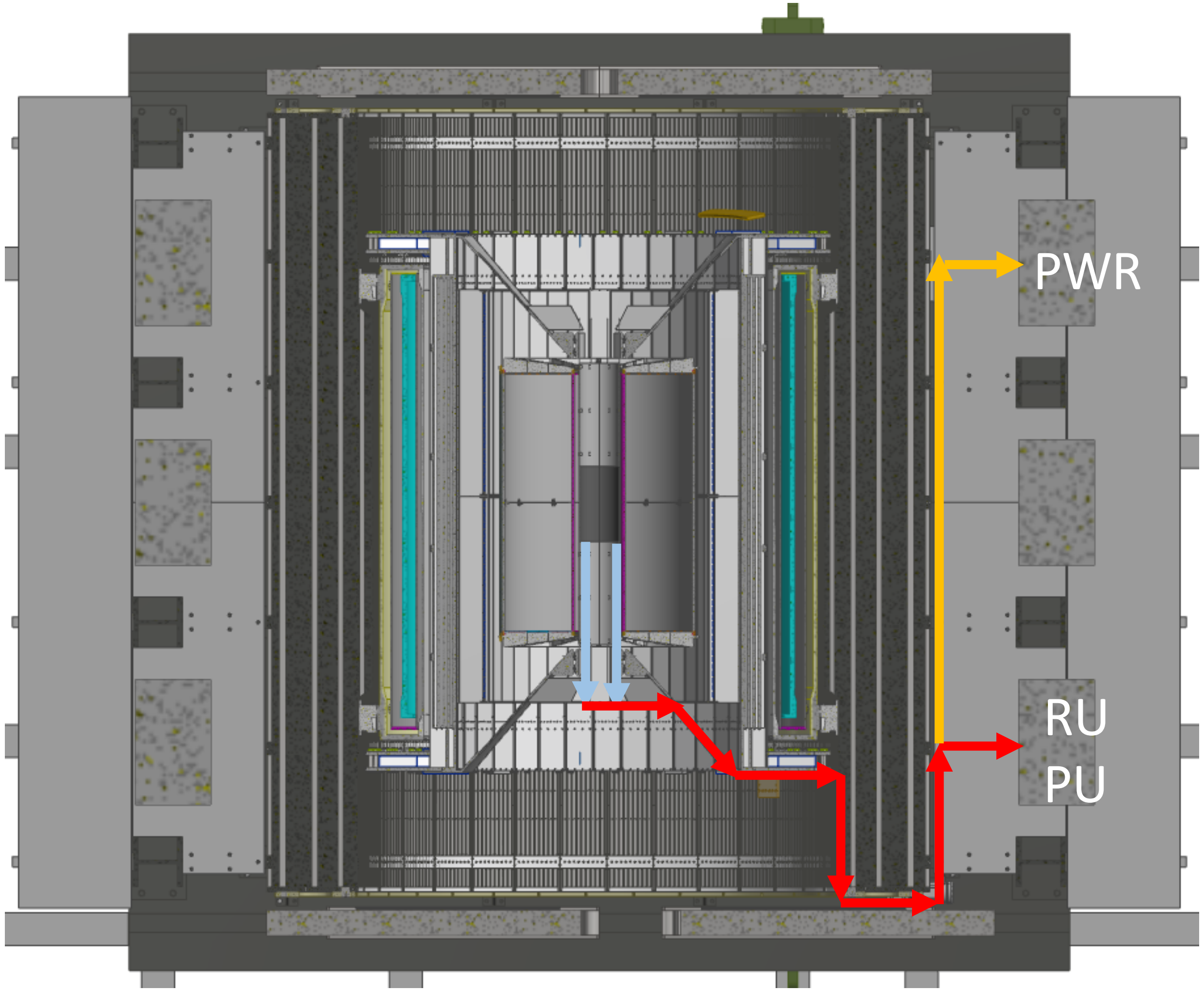


Confirmed New MVTX Long SamTec Readout Cables

8.8m + 2.6m = 11.4m (10m desired for sPHENIX; ALICE 8m cables)



MVTX Readout and Power Cable Route



BNL has approved “non-halogen free” cables for sPHENIX

ALICE ITS/IB final readout cables: ~8m

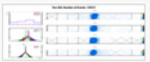
sPHENIX MVTX: 7.9+m

- Cable-A: 1.4 m
- Cable-B: 6.5+ m
- Power cable:4.7+ m

Desired ~10m

LongRunList

[edit]

pKey	run	time	Beam Angle	tableX (mm)	tableY (mm)	beamEnergy (GeV)	beamParticle	comment	eventDisplay
1	0831								 run 0831
2	0847								 run 0847
3	0848	5-20-2019 19:34:37		1095.5	270.1	120	Proton		 run 0848
4	0849	5-20-2019 19:34:37		1095.5	270.1	120	Proton		 run 0849
5	0850	5-20-2019 19:34:37		1095.5	270.1	120	Proton		 run 0850
6	0851	5-20-2019 19:34:37		1095.5	270.1	120	Proton		 run 0851
7	0852	5-20-2019 19:34:37		1095.5	270.1	120	Proton		 run 0852
8	0853	5-20-2019 19:34:37		1095.5	270.1	120	Proton		 run 0853
9	0854	5-20-2019 19:34:37		1095.5	270.1	120	Proton		 run 0854

- Data run-log in sPHENIX Wiki,
  Nice work by Xiaochun et al. @GSU
- Jin's test beam analysis framework
  Offline analysis in progress

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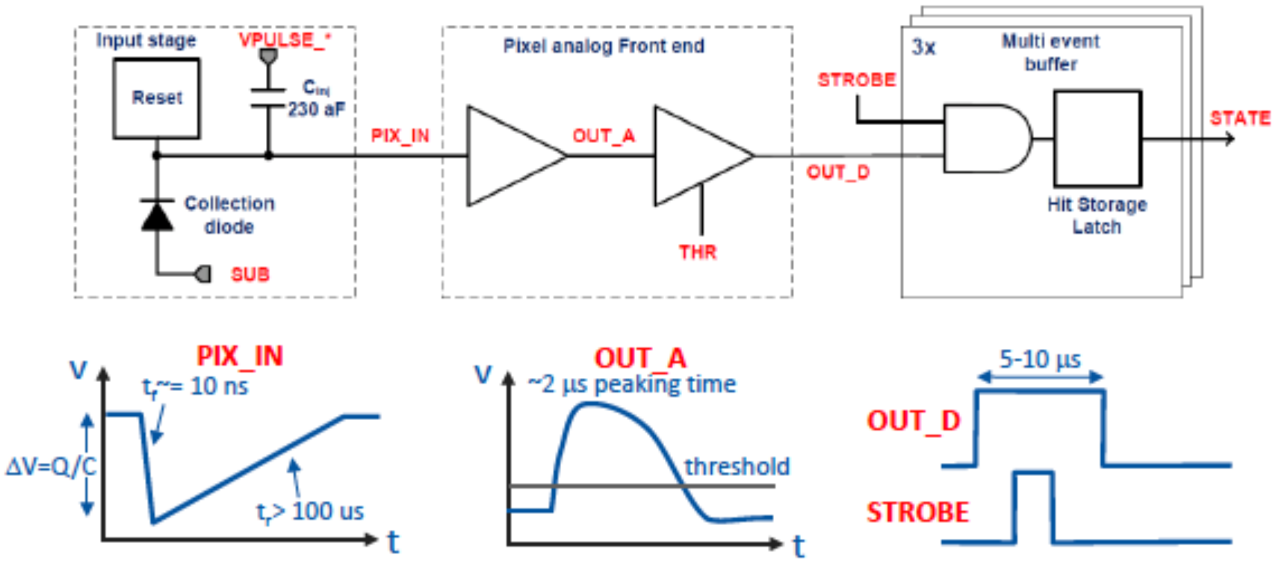
MVTX Goals – the 2nd TB, 6/17-22, 2019

- Test and confirm optimal MVTX operation parameters for sPHENIX
  - Threshold scan, analogy shaping time etc.
  - Study chip hit efficiency vs trigger(strobe) latency
    - dT = 1 ~ 10 uS
    - Impact on occupancy & pileup
- Parameters predetermined from laser scan at LANL, in good progress
    - Single chip readout with MOSAIC with pulsed laser (~MIP)
    - Threshold and noise
    - Analogy shaping time
    - Strobe delay and length

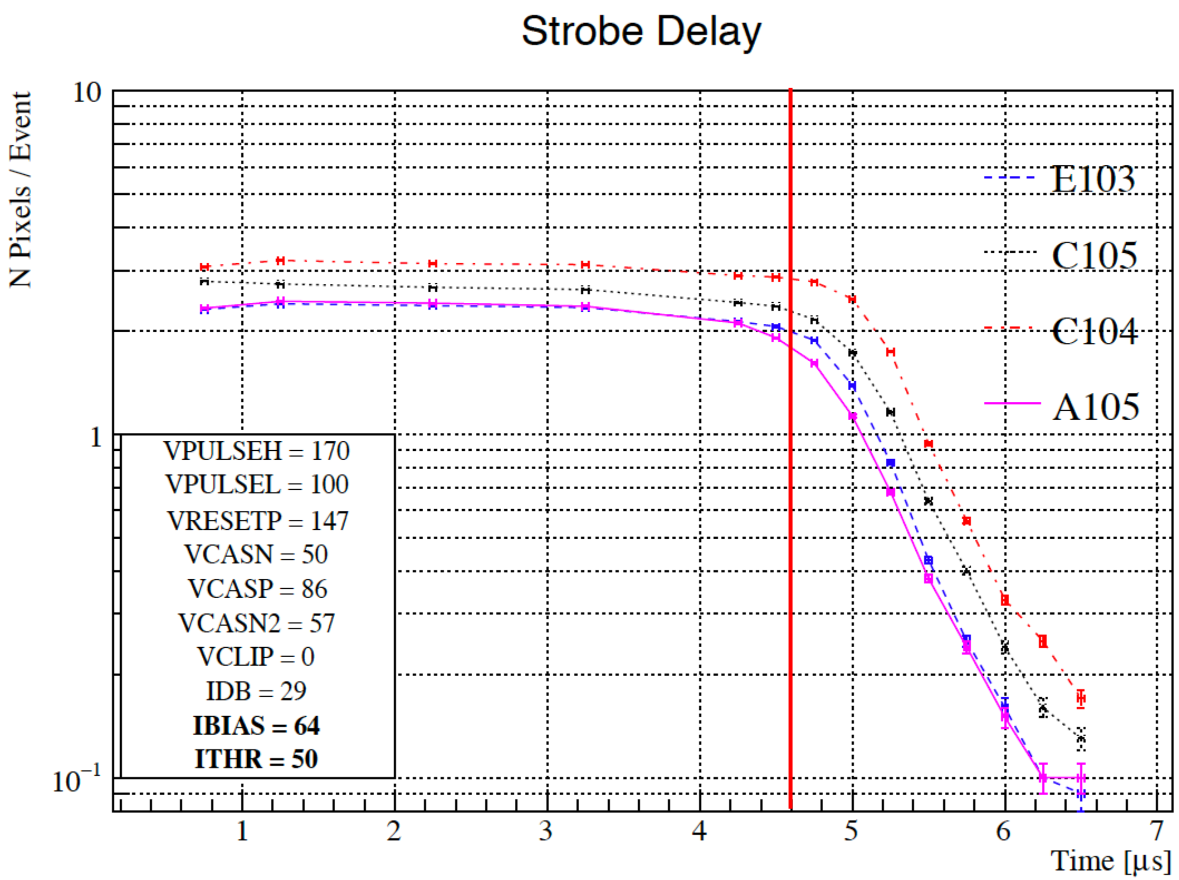


ALPIDE Sensor Operation Optimization

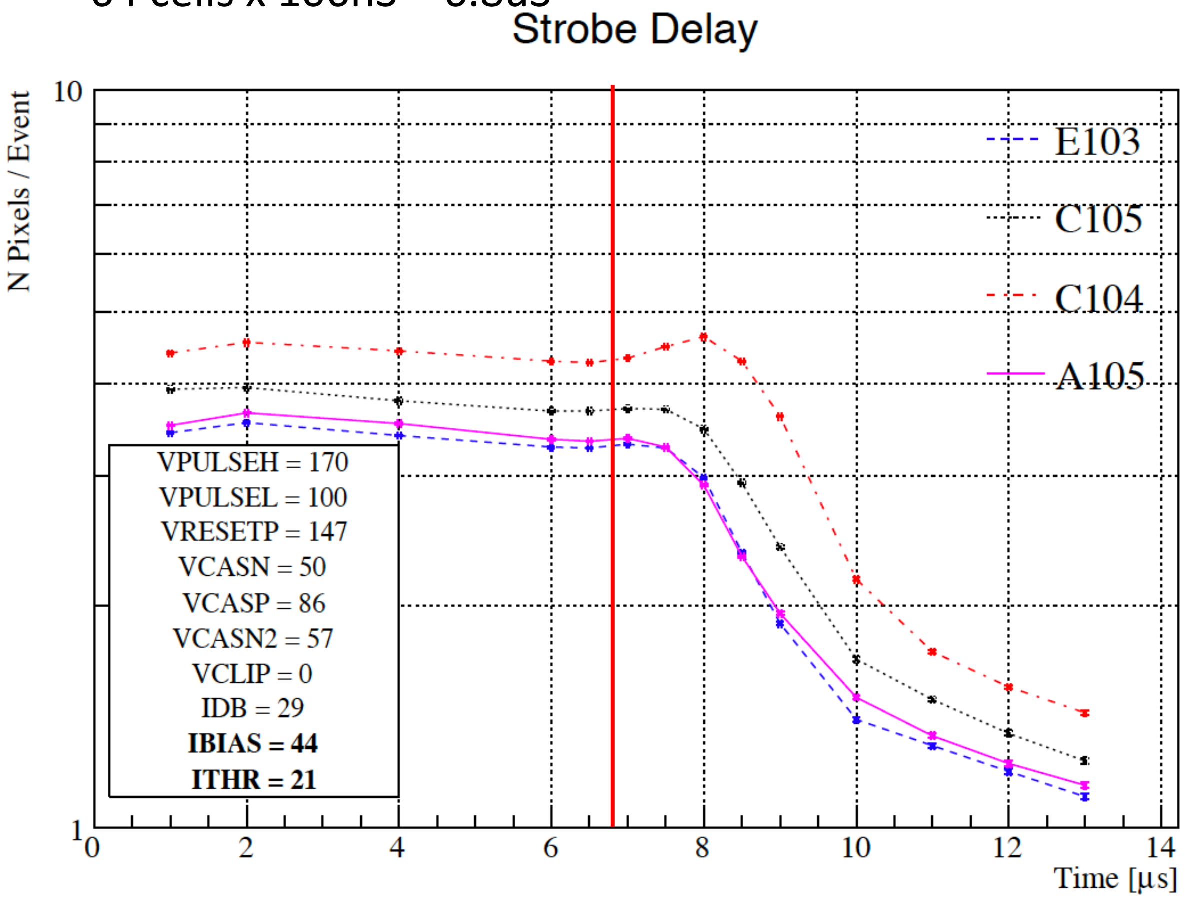
"ALICE Default Settings"
- "Pile up" integration time ~ 5uS

"Stretched Settings" for sPHENIX trigger study
- Pile up integration time ~ 8uS

64 cells x 106nS = 6.8uS



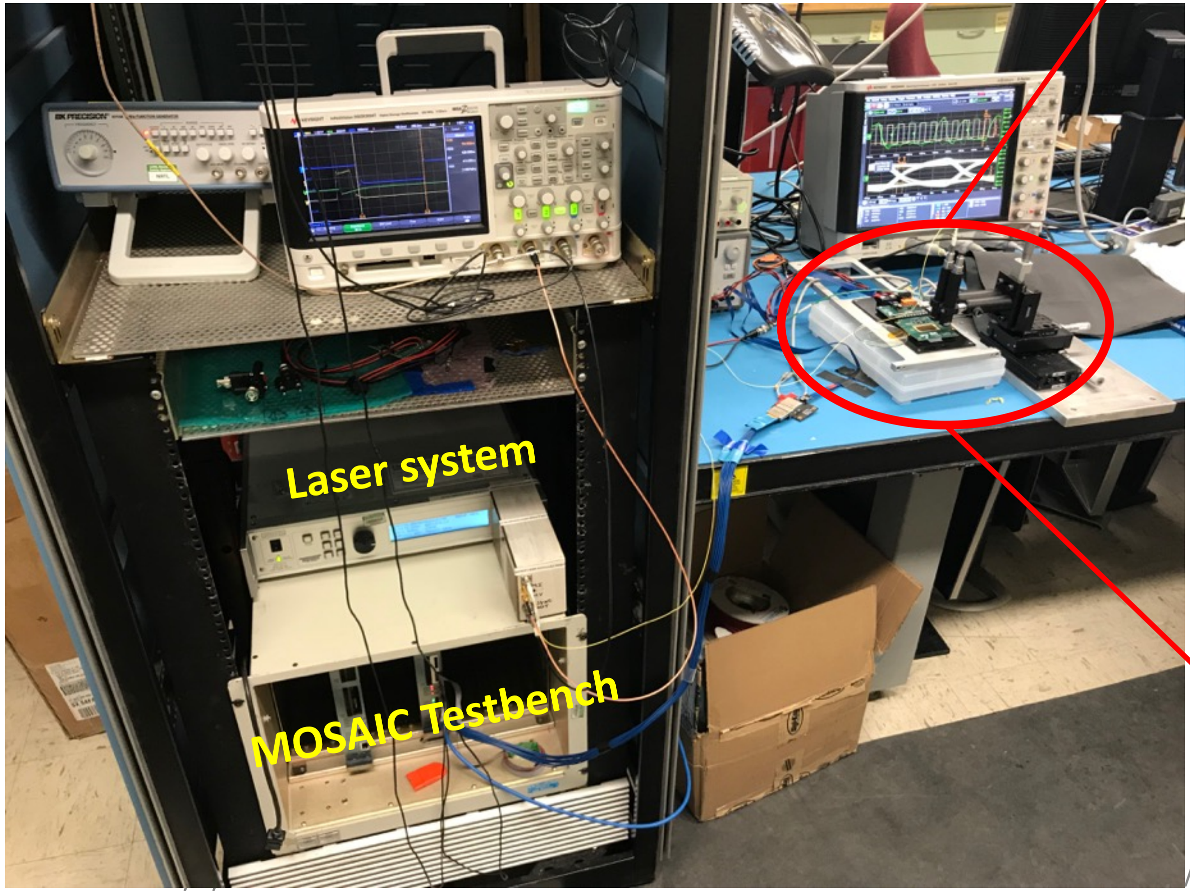
sPHENIX Trigger Latency ~ 4.7uS

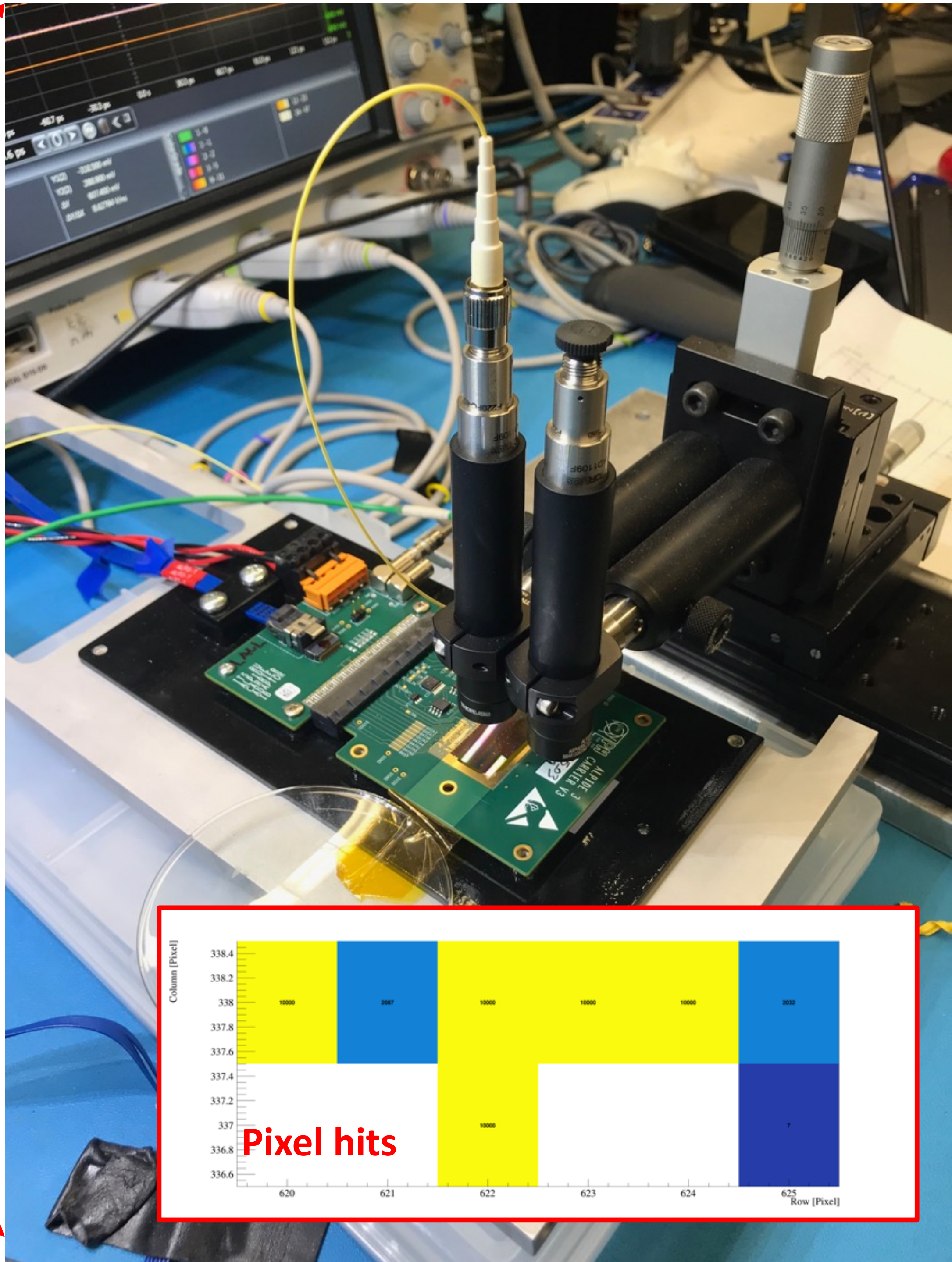


sPHENIX Trigger Latency ~ 6.8uS

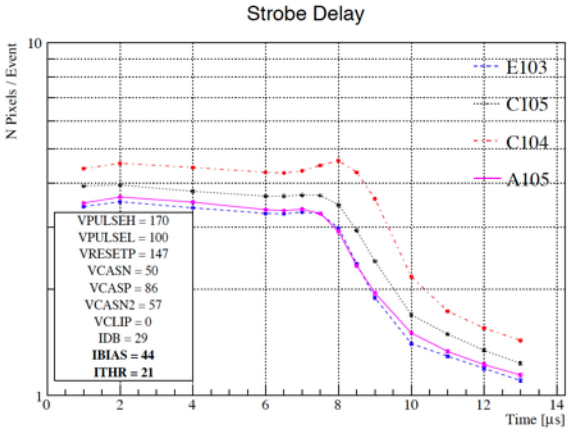
Study MAPS Performance with Pulsed Laser @LANL

- Inject "MIP" signal, focused laser beam
  - 850 nm laser, 4ns wide pulse, ~1 MIP
  - 50kHz trigger
  - **Find optimal MAPS operating parameters**

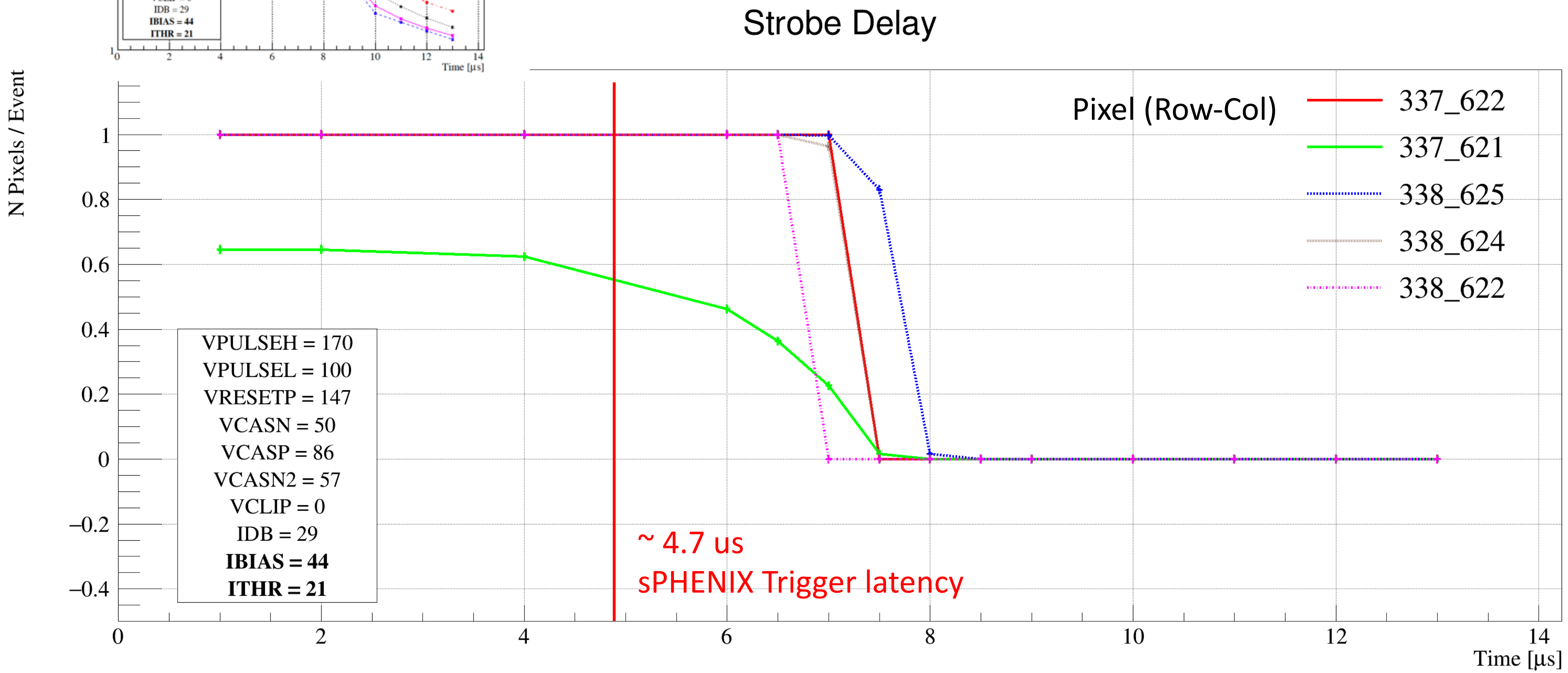




Laser Scan Data – Pixel Hit Efficiency vs Trigger Delay



One of "Stretched Settings" for sPHENIX trigger
MAX: 64 cells x 106nS = 6.8uS



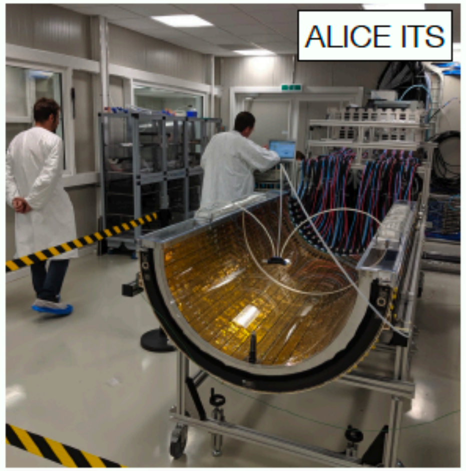
MVTX experts help ALICE/ITS – to help us!

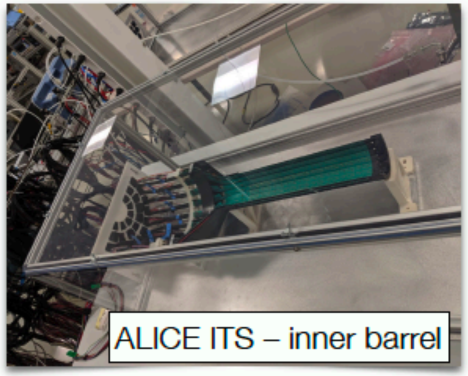
Dave's talk
from Monday

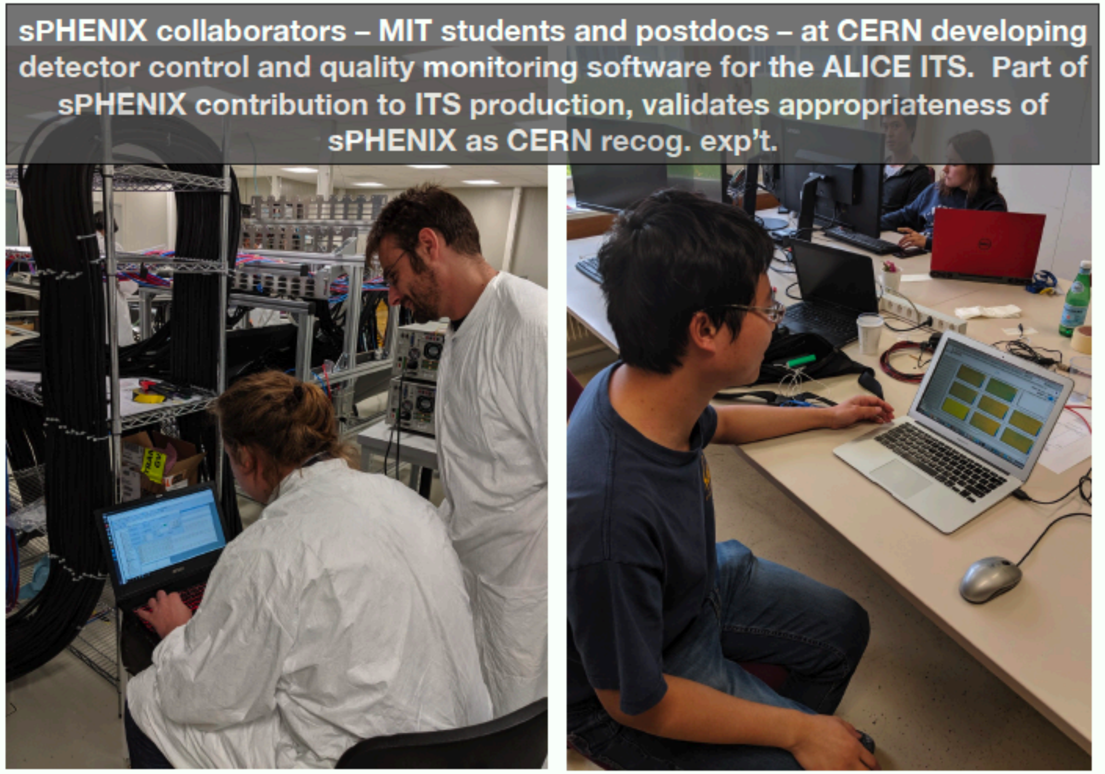
ITS surface commissioning now:
~ May 2020

- Great opportunity to learn about ITS/MVTX detectors
- Training on technical details
- Developing tools
- Build up operation experience

The ALICE ITS lab at CERN







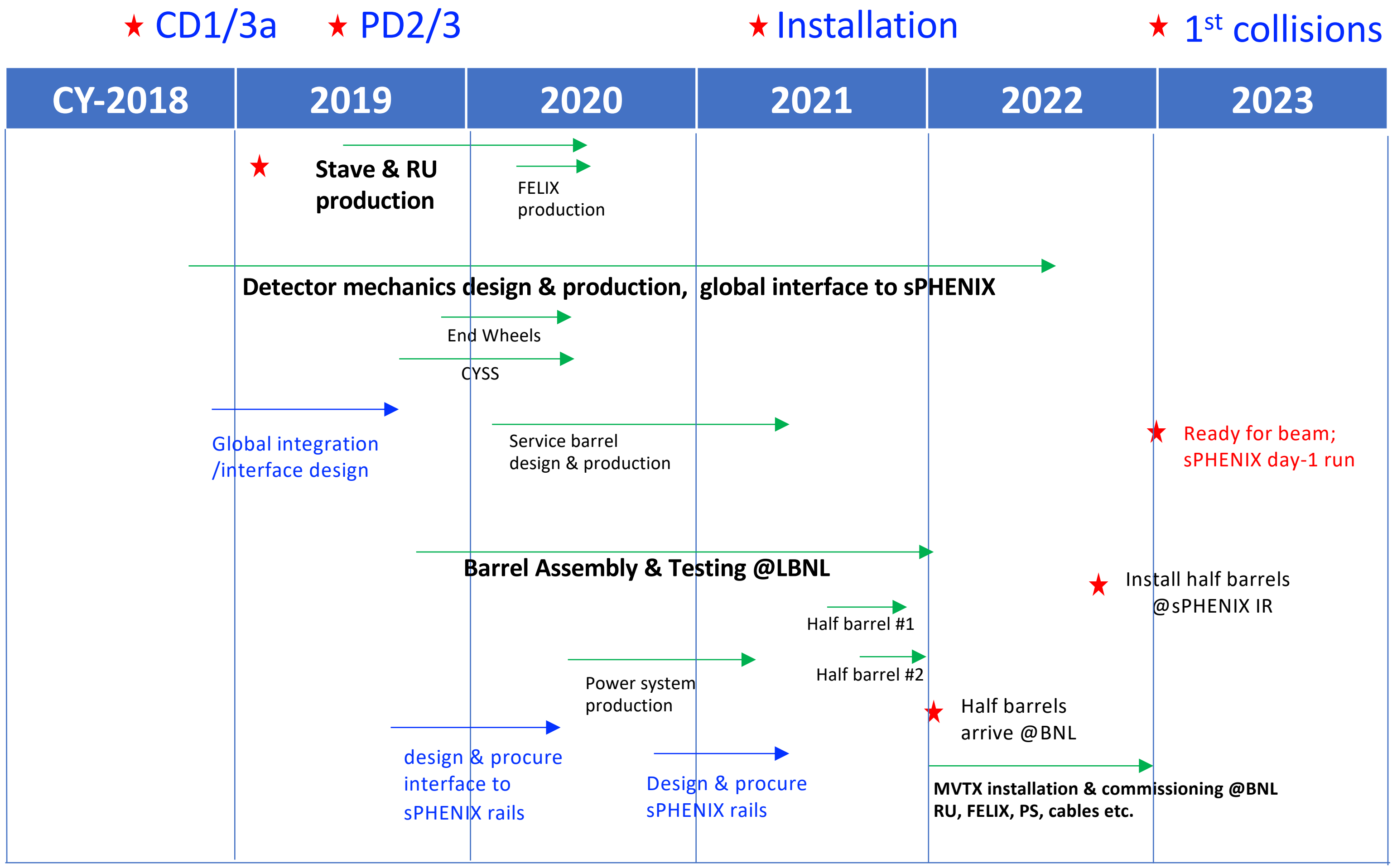
Funds from BNL sent to CERN to build add'l staves of ITS IB design, to be shipped to BNL.

20

MVTX Schedules and Milestones (3/2019) concerns & challenges

sPHENIX:

MVTX



Funding delays –

- Stave production delayed at CERN
  - Impact on following test & assembly
  - preparation work @LBNL, UT-A

- Lack of R&D $ for mech. desgin work
  - MIT, LBNL, LANL
  - “advanced cash” running out MIT, LANL

Running low in schedule contingency …

Report from April BNL PD2/3 Reviews: Silicon Detectors - MVTX, INTT

Silicon Detectors & Mechanical Integration - Bill Wahl (BNL), Paul O'Connor (BNL), Sven Herrmann (BNL)

Acknowledgements
The sub-committee commends the INTT & MVTX detector projects for their state of technical readiness. The designs are very mature for a project at pre-PD1 and the decision to leverage experience from past projects will likely result in cost savings and significant risk reduction.

Committee Response to Review Charge

1. **Conceptual Design:** Is the conceptual design sound and likely to meet the project's technical performance requirements most efficiently and effectively?

   Response: Yes. Both detectors rely heavily on prior experiments, which is a wise and conservative strategy. Further work is needed, which is well understood by both detector projects as they work towards a final design.

2. **Project Scope:** Are the project's scope and specifications sufficiently defined to support the preliminary cost and schedule estimates? Are the interfaces with the sPHENIX MIE project and the Infrastructure and Facility Upgrade Project properly understood and documented?

   Response: Yes (qualified). The technical specifications for both detector projects are generally understood and well aligned with cost & schedule estimates. Better definition of flow-down requirements should be articulated by the project to best support science objectives. Both silicon detector projects appear to be working closely with the Office of System Integration (OSI) to establish and comply with interface requirements.

3. **Risks:** Are the project risks properly identified and appropriate mitigation strategies in place?

   Response: No. For both detector projects, a limited number of Risks have been identified, which the committee feels is unrealistic considering the scope and complexity of each project. The methodology for managing Risks is inconsistent with the rest of the project.

4. **Cost and Schedule:** Are the cost and schedule estimates credible and realistic for this stage of the project? Do they include adequate scope, cost, and schedule contingency?

   Response: Yes (qualified). Yes, for this stage of the project, but further work is needed to develop a defendable baseline. INTT contributed labor for management is not captured in the plan or BOE.

5. **Management:** Is the project being properly managed at this stage? Is the documentation appropriate at this stage of the project?

   Response: Yes (qualified). The committee says yes but only at this pre-PD1 stage. Further work is needed for both projects to develop the necessary management tools to be consistent with the rest of the project.

6. **ES&H:** Is ES&H being properly addressed given the project's current stage of development?

   Response: Yes. Planned usage of ES&H best practices were communicated by both silicon detector projects.

Comments

1. The MVTX staves are part of a common production at CERN for both ALICE and sPHENIX. Staves are produced in three performance grades ("gold", "silver", "bronze"). Both ALICE and sPHENIX plan to accept both gold and silver staves. However, the distribution of gold and silver staves has not been established for either project. The MVTX should specify the minimum acceptable number of gold staves to meet their tracking requirements.
2. A milestone master list and possibly a corresponding Milestone Dictionary for both projects should be made available for future reviews.
3. The WBS Dictionary and Critical Path for the MVTX & INTT should be posted to the PD2/3 review site ahead of the next review.
4. Detailed mock-ups for both silicon detectors should be constructed to minimize conflicts during integration (piping, cabling, support, etc.).
5. For both Silicon Detector projects, FTE requirements were not articulated in the presentations. At future reviews, it would be best to have a slide that speaks to FTE requirements by resource type.

Issues & Concerns
As a project, there appears to be a general reluctance to add risks to the Risk Registry. Known Risks should be included in the Registry, even those with a low probability. This approach will make it clear to future reviewers that Risk management is fully embraced by the project and risks are not being overlooked.

1. Silicon Detector Risks are being managed differently than the rest of the project. Early adoption of the standard format would be most appropriate.

2. For the MVTX, there needs to be better alignment between the spending and funding profile as they are currently out of phase. In fact, activities such as Stave testing are currently delayed due to the unavailability of funds.
3. It appears that work on MVTX has started at institutions with the expectation that payment will be made after the fact. It is not clear what agreements are in place that would authorize the start of work.
4. Resources for MVTX software development are not represented in the schedule. Planning is underway, but it is important to finalize resource needs and include them in the plan as early as possible.
5. The MVTX project only has 6 months of float, which might not be enough, especially since some activities are already behind schedule due to funding availability.
6. The INTT project needs electrical engineering resources, which is not reflected in the current plan and still needs to be negotiated between BNL & RIKEN.
7. It is not clear if the INTT and MVTX projects will follow EV reporting. If they will, there are missing aspects of the plan that would need to be addressed prior to setting the baseline (labor hours on activities, timing of payments to vendors, etc.).
8. It appears the WBS Dictionary, BOE, and Risk Registry for both Silicon Detectors are not integrated into sPHENIX.
9. The MVTX project did not present documentation that suggests it is following the same PM methods as the other sPHENIX subsystems (WBS Dictionary, Primavera P6 format, etc.) which suggests it is not part of an integrated schedule.
10. Funding for INTT management activities is contributed by BNL but it is not identified in the plan.
11. The proposed design changes for the sPHENIX beampipe and beampipe support to accommodate the MVTX seems nontrivial and still requires buy-in. This Risk should be held at the project level and settled reasonably soon.
12. The INTT Flex bus extender is made from Liquid Crystal Polymer (LCP) instead of Polyimide due to its smaller loss tangent but LCP is a less mature technology and not as robust as Polyimide.

Recommendations (1 & 2 to be completed prior to MIE PD-3. 3-11 to be completed by the end of the calendar year)

1. Clearly articulate requirements flow-down and margin analysis during future plenary sessions. [Note: This would also be useful for the full sPHENIX scope as noted earlier in the report.]
2. Develop a clear methodology for performing verification/validation against specifications and interface requirements.
3. Develop a detailed set of key milestones to ensure the same level of rigor is applied relative to the MIE and Infrastructure/Facility parts of the project. (recommendation for MVTX & INTT)
4. Clearly document and communicate change control and configuration control methods at partnering institutions and the eventual roll-up to BNL. (recommendation for MVTX & INTT)
5. Generate a list of early funding needs (similar to CD3a) to address near-term schedule delays that will be realized if funding doesn't become available. (recommendation for MVTX & INTT)
6. Enumerate all contributed labor and resources and establish commitment level from institutions by way of MOAs/MOUs (including management and software). (recommendation for MVTX & INTT)
7. Establish a clear policy for contingency at partnering institutions that are participating in the MVTX project (specifically contingency ownership & authority).
8. Generate a comprehensive list of Risks, which should be included in the Risk Registry. (recommendation for MVTX & INTT)
9. Establish the likelihood for metal particulate generation that can come in contact with wire bonds and pads and develop methods to protect them. (recommendation for MVTX)
10. Develop KPPs for the Silicon Detectors, which will establish the basis for determining project success. (recommendation for sPHENIX management)
11. Document and communicate the scientific need for both the silicon detectors. (general recommendation for sPHENIX)

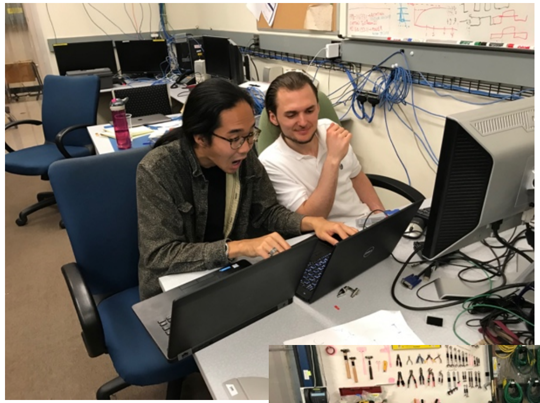
- MVTX Risks - all in P6 now
- WBS, PMP documents updated
- Schedule & Labor profile updated in P6 (Glenn, Irina)

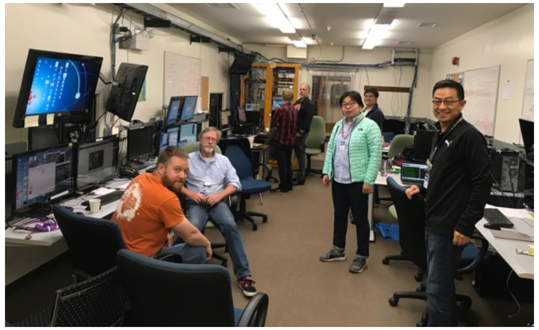
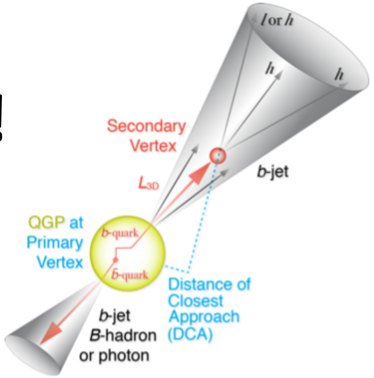
Need project fund NOW to meet the goals!

Summary

- Completed essential R&D for readout integration
  - Full 9-chip stave readout per RU
  - Multi-RU readout per FELIX
  - Long readout cables
  - sPHENIX GTM
- Completed preliminary mechanical design
- Improve MC detector response, clustering – in progress
  - Calibration data with incident angles, 0, 10,20,30,40,45
- Stave and RU production at CERN - in good progress
- MVTX Cost & Schedule review, July 29-30 @BNL

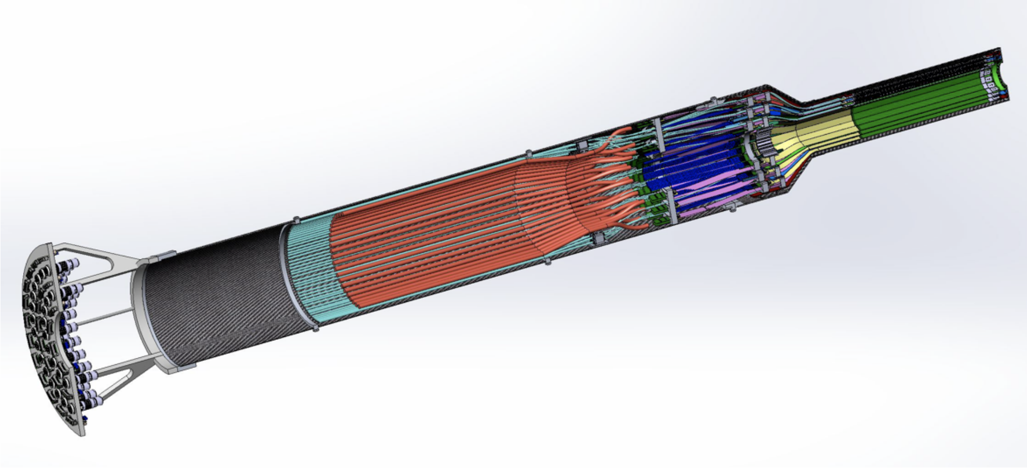
We are ready for the full production and the physics!



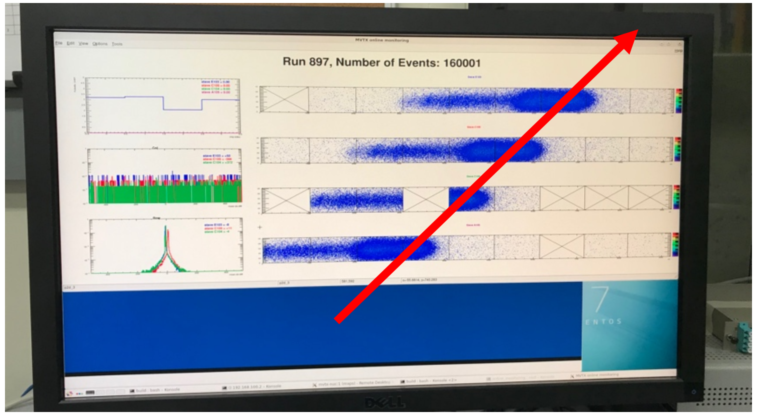




R&D Highlights

- Very successful TB at Fermilab, 5/13-25, 2019
  - Confirmed the long 11.4m SamTec readout cable
  - Confirmed the full stave readout
  - Confirmed multi-RU readout per FELIX
  - Confirmed sPHENIX GTM with FELIX
- A 2nd TB, study optimal MAPS operation points
  - Parasitic with INTT+TPC, 6/17-21



- Preliminary mechanical design developed
  - To prototype CYSS and Layer-2 End-Wheel this summer
  - France, Italy, CERN, contacted and under discussion
- Improve MC detector response, clustering – in progress
  - Took calibration data with incident angles, 0, 10,20,30,40,45



- TB later at LBNL/LANL – in preparation
  - Scan stave material budget with 50MeV p-beam
  - 8-stave + 8-RU +1-PU + 1-FELIX + 1-GTM + RCDAQ, the full complete readout chain
    - Hardware will be available soon

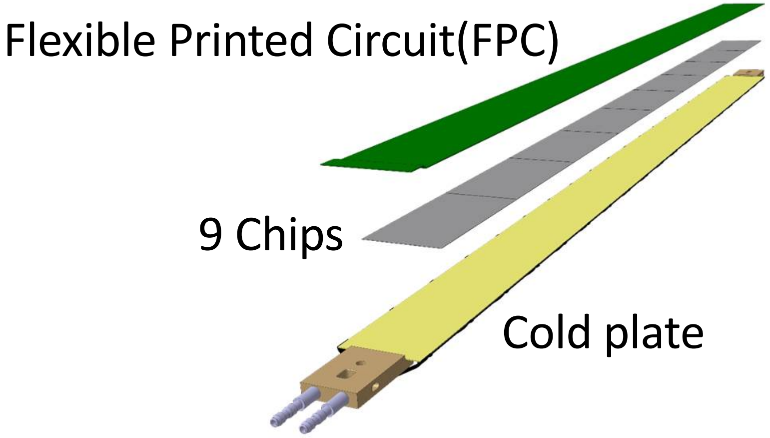
Monolithic Active Pixel Sensors (MAPS)

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

Advantages of ALICE PIxel DEtector (ALPIDE) sensor:

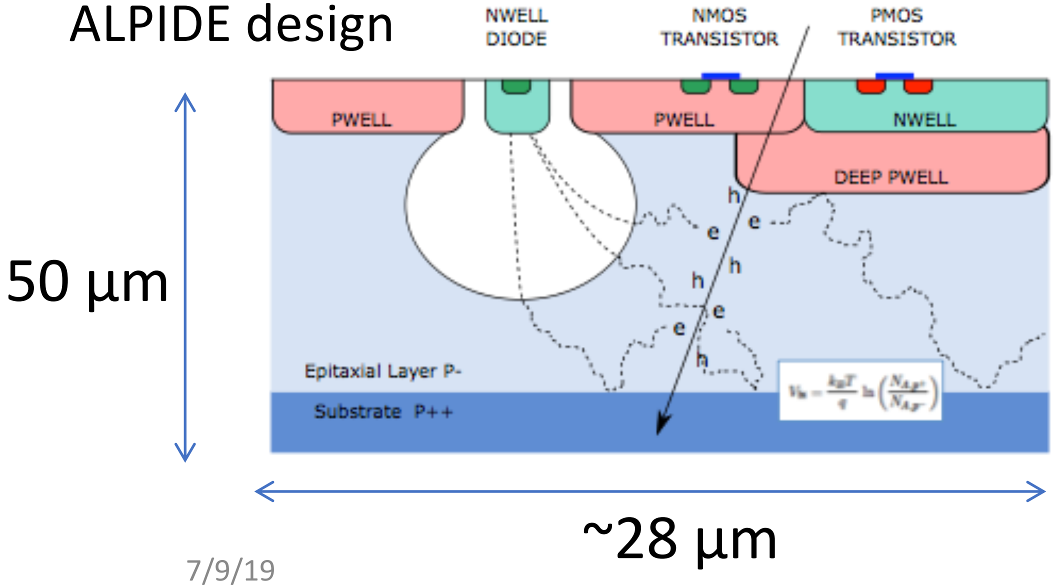
- Very fine pitch (27µm x 29µm), for superb spatial resolution
- High efficiency (>99%) and low noise (<10^{-6}), for excellent tracking
- Time resolution, as low as ~5 µs, for less pileup
- Ultra-thin/low mass, 50µm (~0.3% X_0), for less multiple scatterings
- 0.5M channels with on-pixel digitization, for zero-suppression and fast readout
- Low power dissipation, 40mW/cm², for minimal service materials

An ideal detector for QGP physics!



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

ALPIDE design

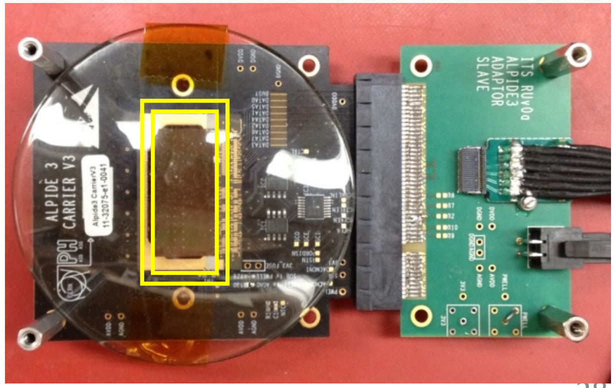


Tower Jazz 0.18 µm CMOS

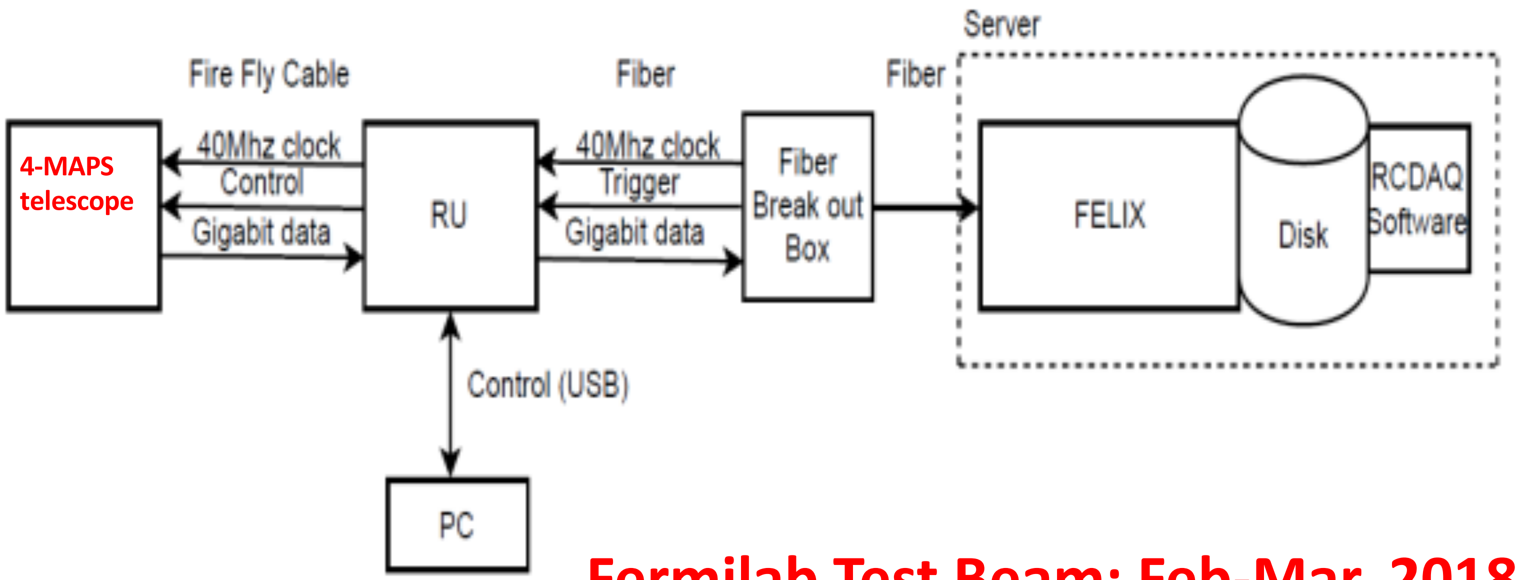
- feature size 180 nm
- metal layers 6
- gate oxide 3nm

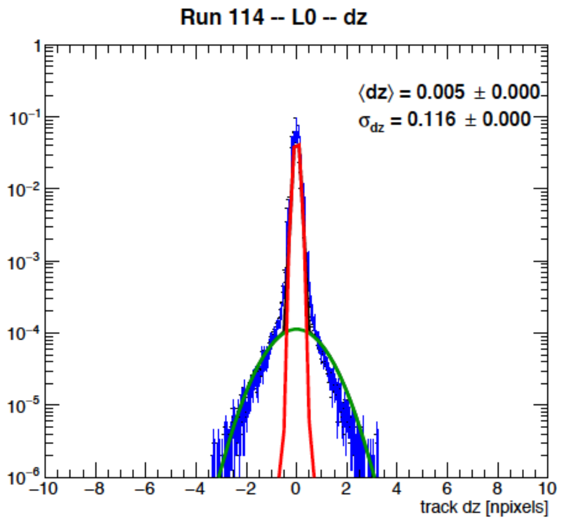
substrate: $N_A \sim 10^{18}$
epitaxial layer: $N_A \sim 10^{13}$
deep p-well: $N_A \sim 10^{16}$

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



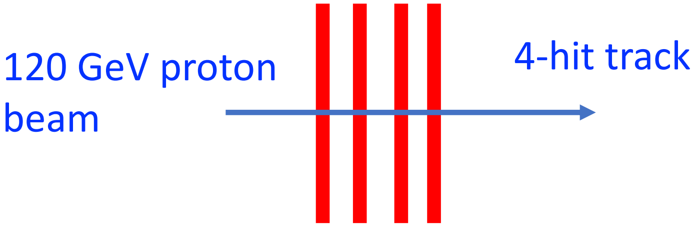
MVTX Full Readout Chain Demonstrated (3/2018)





Tracking spatial resolution achieved: <5 um

Fermilab Test Beam: Feb-Mar, 2018



4-MAPS telescope

www-bd.fnal.gov/synoptic/display/MTest/FTBF_Status

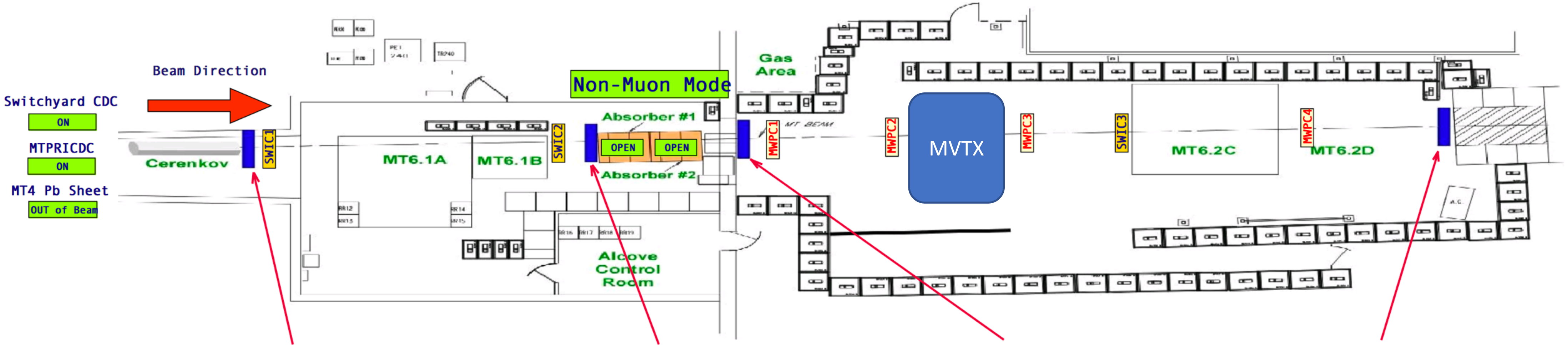
09:04:12

MVTX Test Beam, May 2019

FTBF Status

Mtest Energy: 120 GeV

MTest Mode: Proton



MT6SC1	MT6SC2	MT6SC3	MT6SC4
14926 Cnts	14230 Cnts	12985 Cnts	13786 Cnts

Other Parameters

- Scintillator Counters
- Cherenkov Parameters
- Pinhole Collimators
- Mtest - 17
- TTL Timing
- NIM Timing Marks
- MT6 Environment
- MCenter Environment

Please request intensity from the MCR using F:MTSCL5

SC1+SC2+SC3+Spill (F:MTSCL5) 12388 Cnts

MWPC Triggers 4577 Cnts

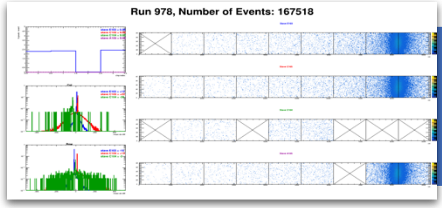
Experiment Triggers 13786 Cnts

Next Spill 52 Sec

Run Types – Details being documented in MVTX wiki

From Xiaochun

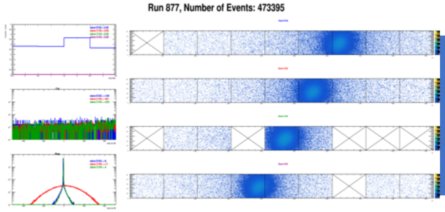
Run0978



Horizontal stave scans (many good runs)

Vertical stave scans

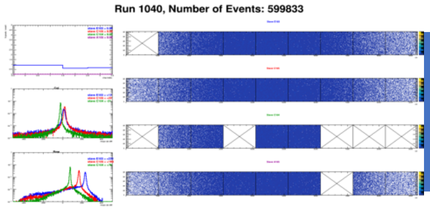
Run0877



Angular stave scans and tilted runs

Extruded aluminum & Lead-block runs

Run1040



Electron beam at 5 GeV (one long run)

4-stave Telescope

120GeV p-beam

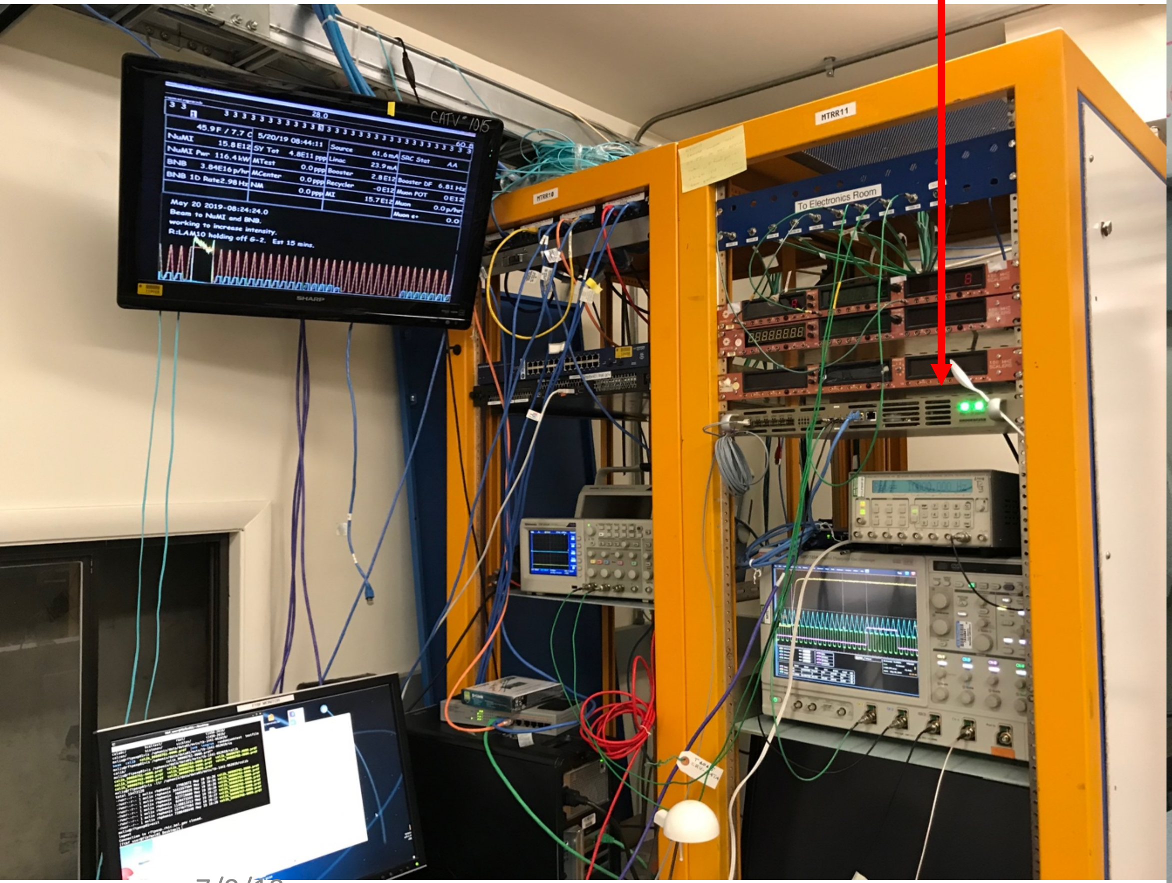
2 RUs,
PU,
PS

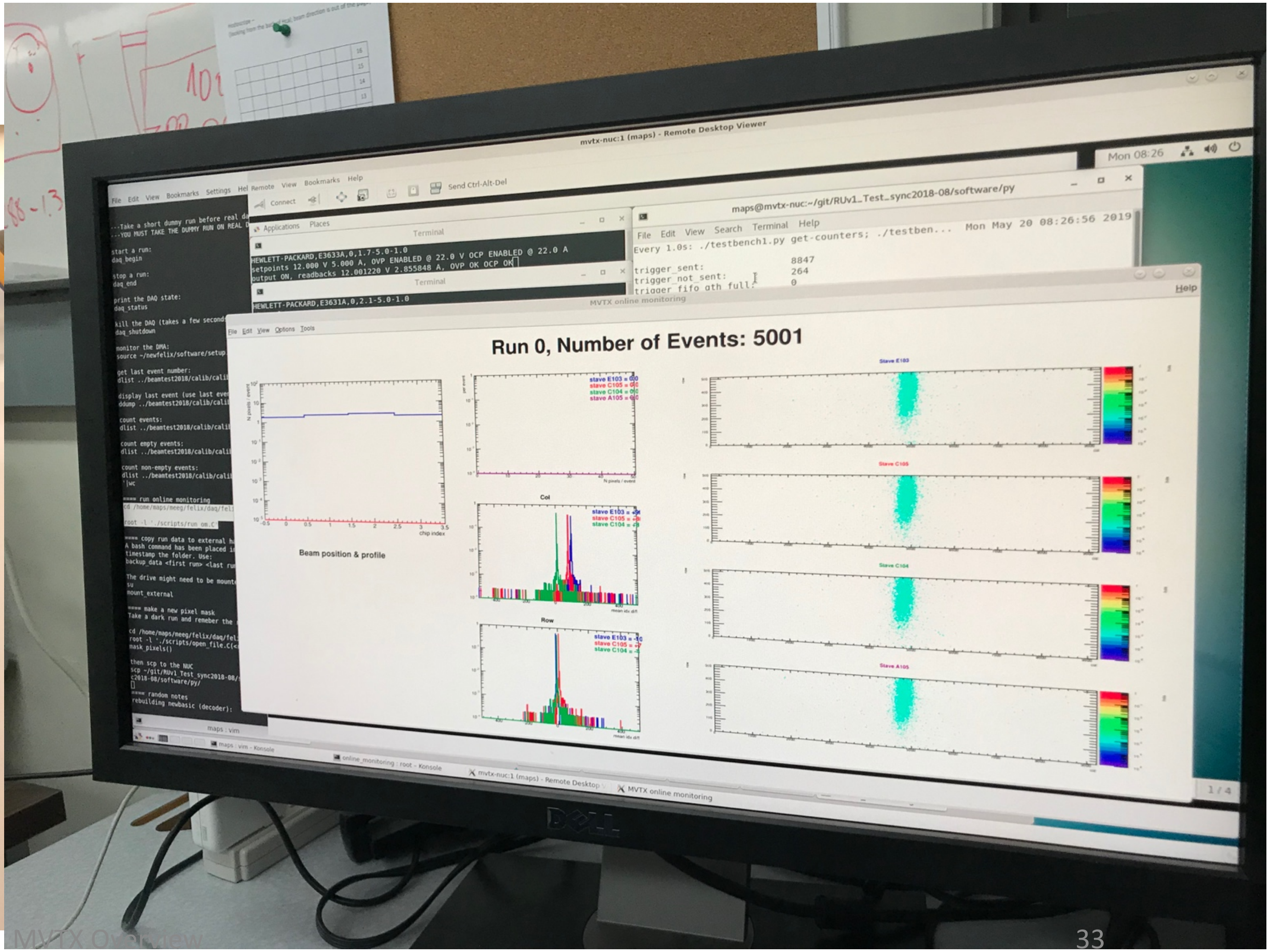
Motion Table
(X,Y,Phi)

Negative Pressure Cooling System

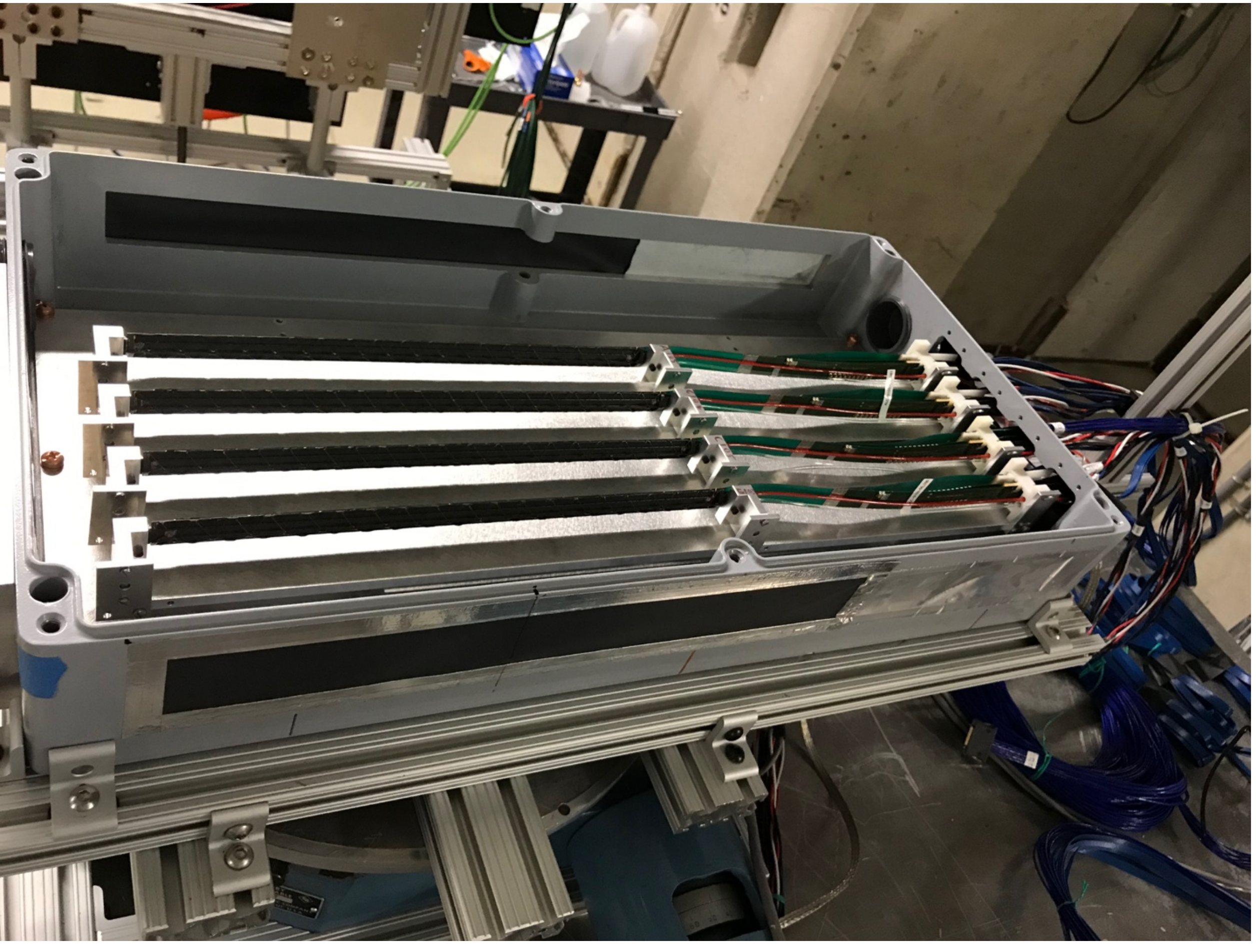
First Collision Signals

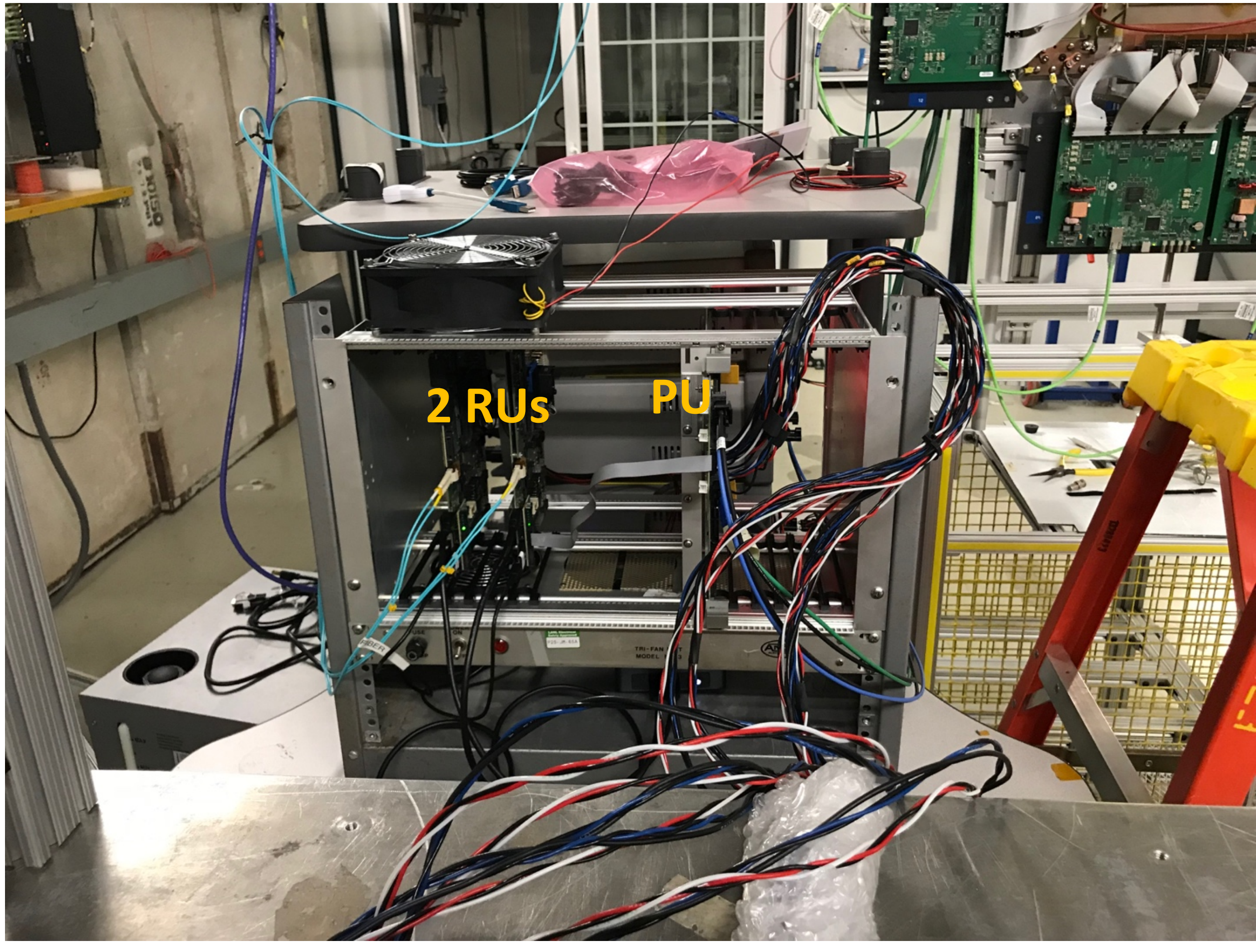
sPHENIX GTM

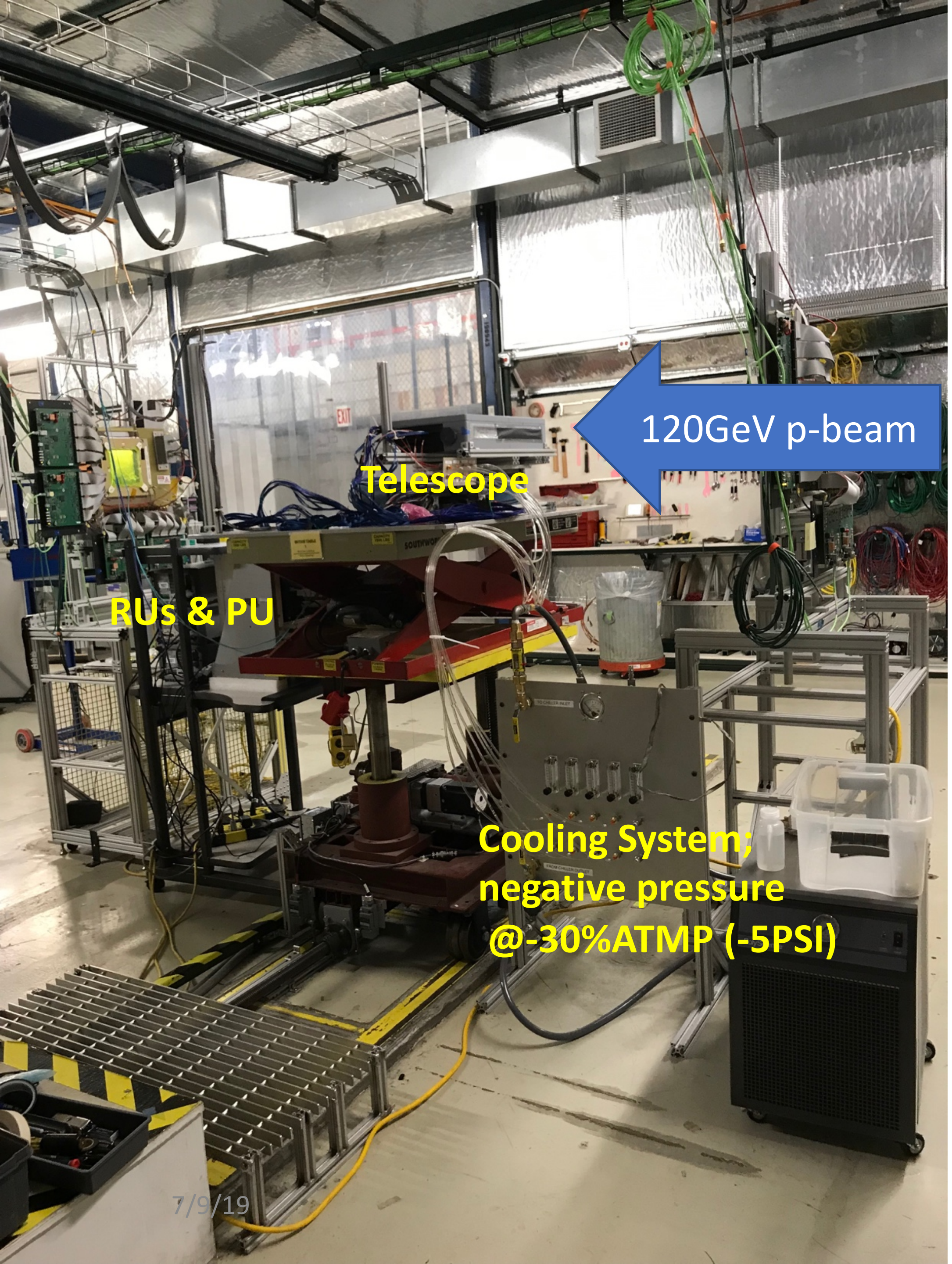


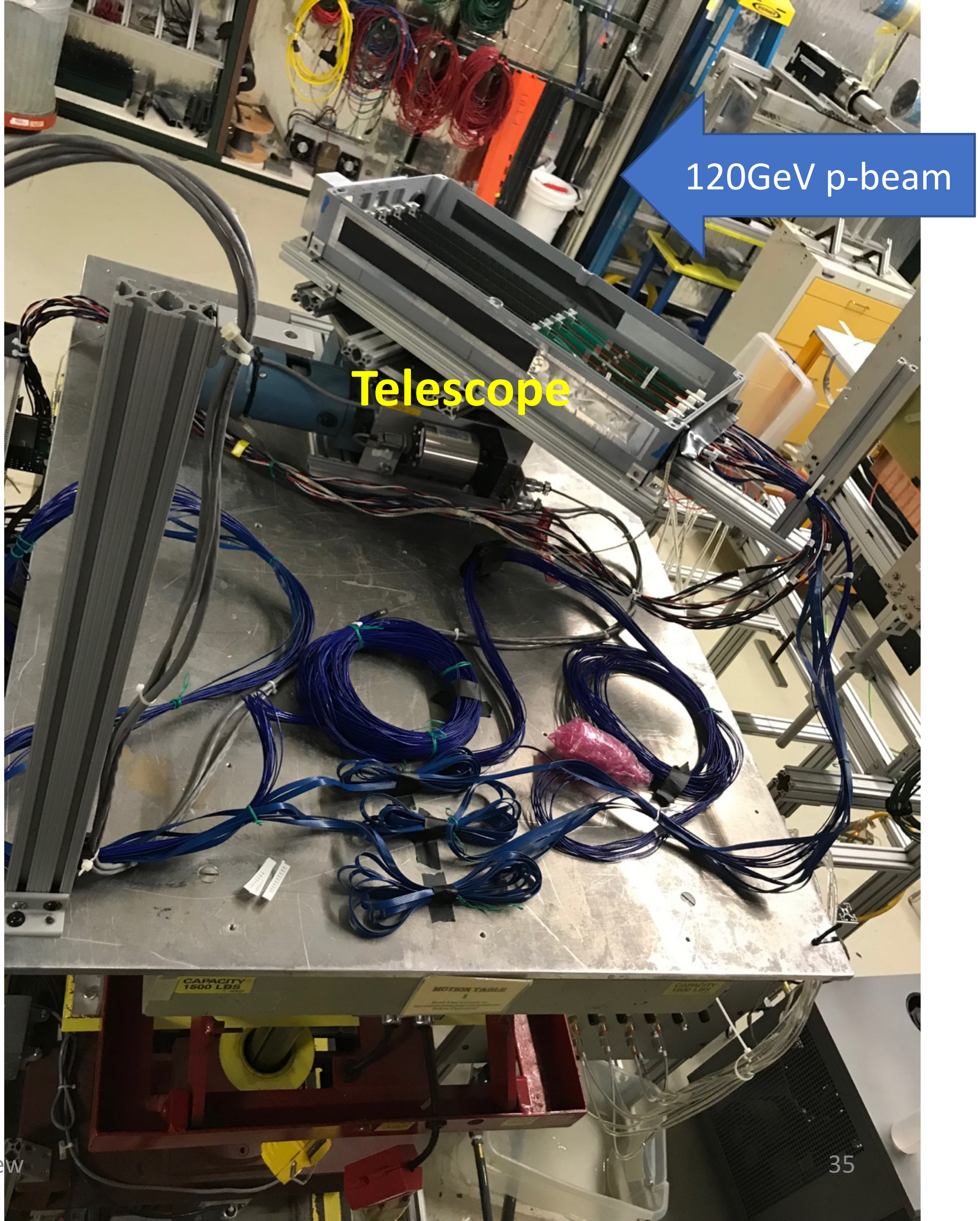


Staves, RUs, PU etc.

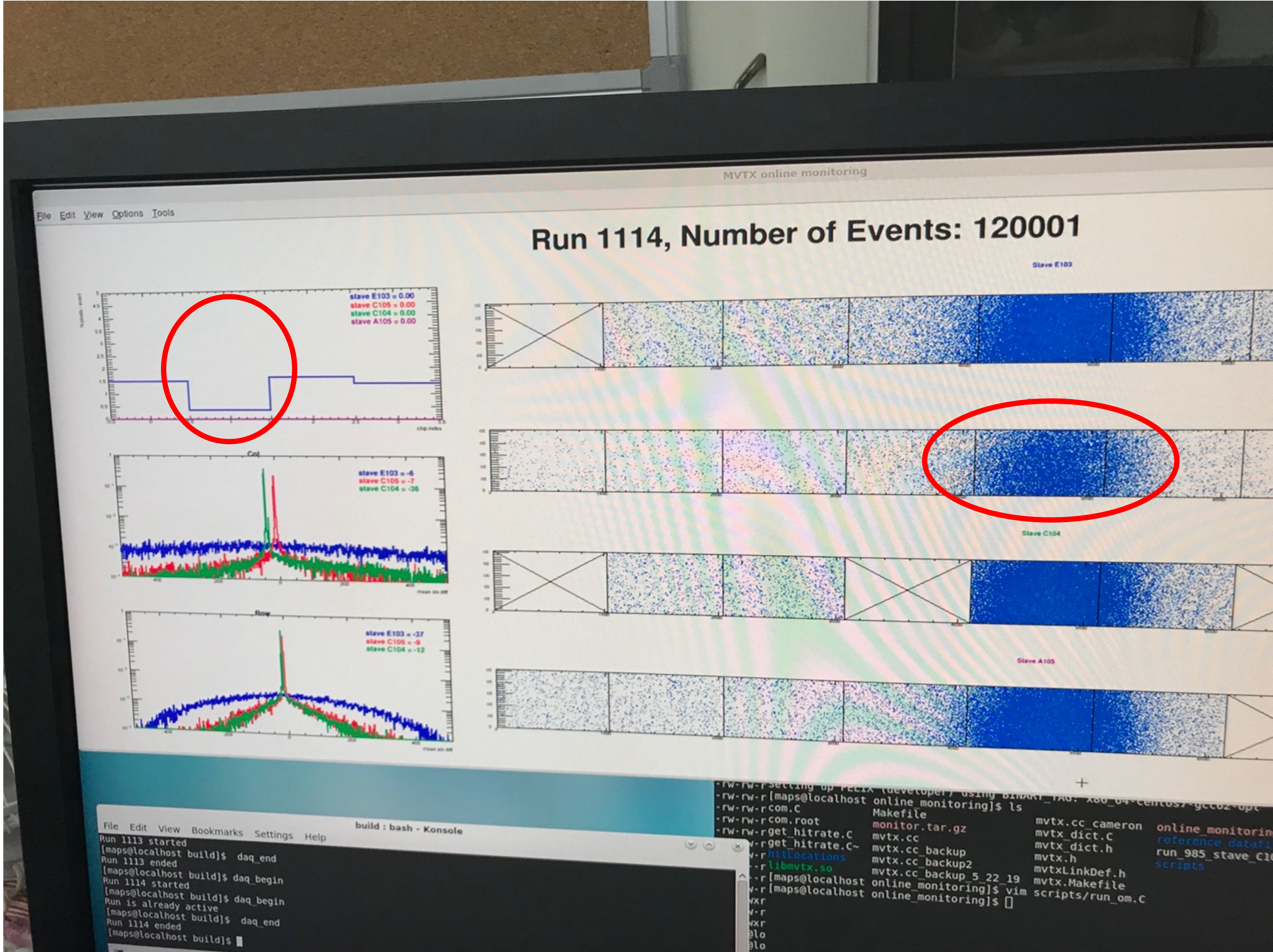




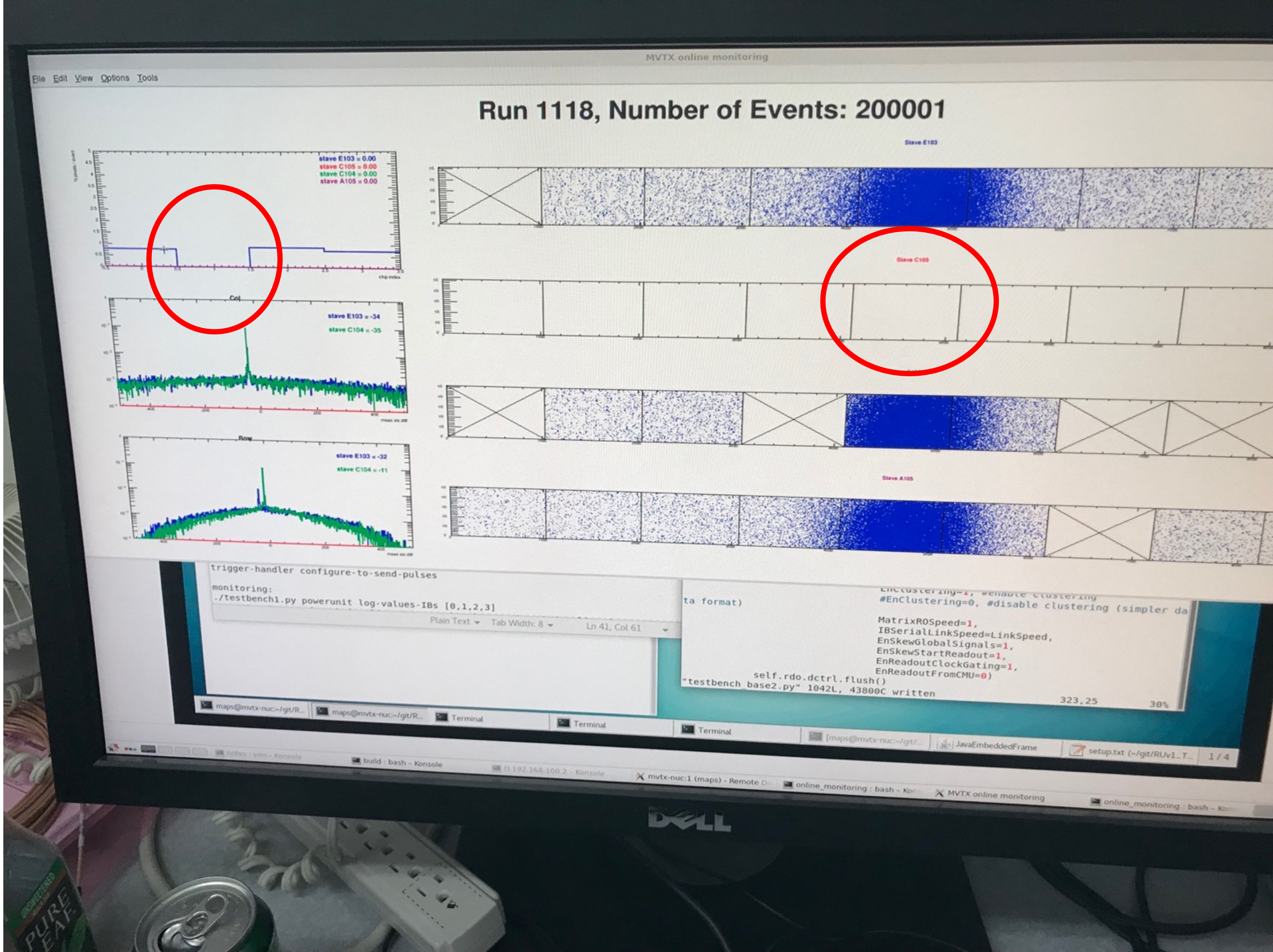

120GeV p-beam
Telescope
RUs & PU
Cooling System;
negative pressure
@-30%ATMP (-5PSI)


120GeV p-beam
Telescope

When MAPS parameters off the optimal point, less hits collected



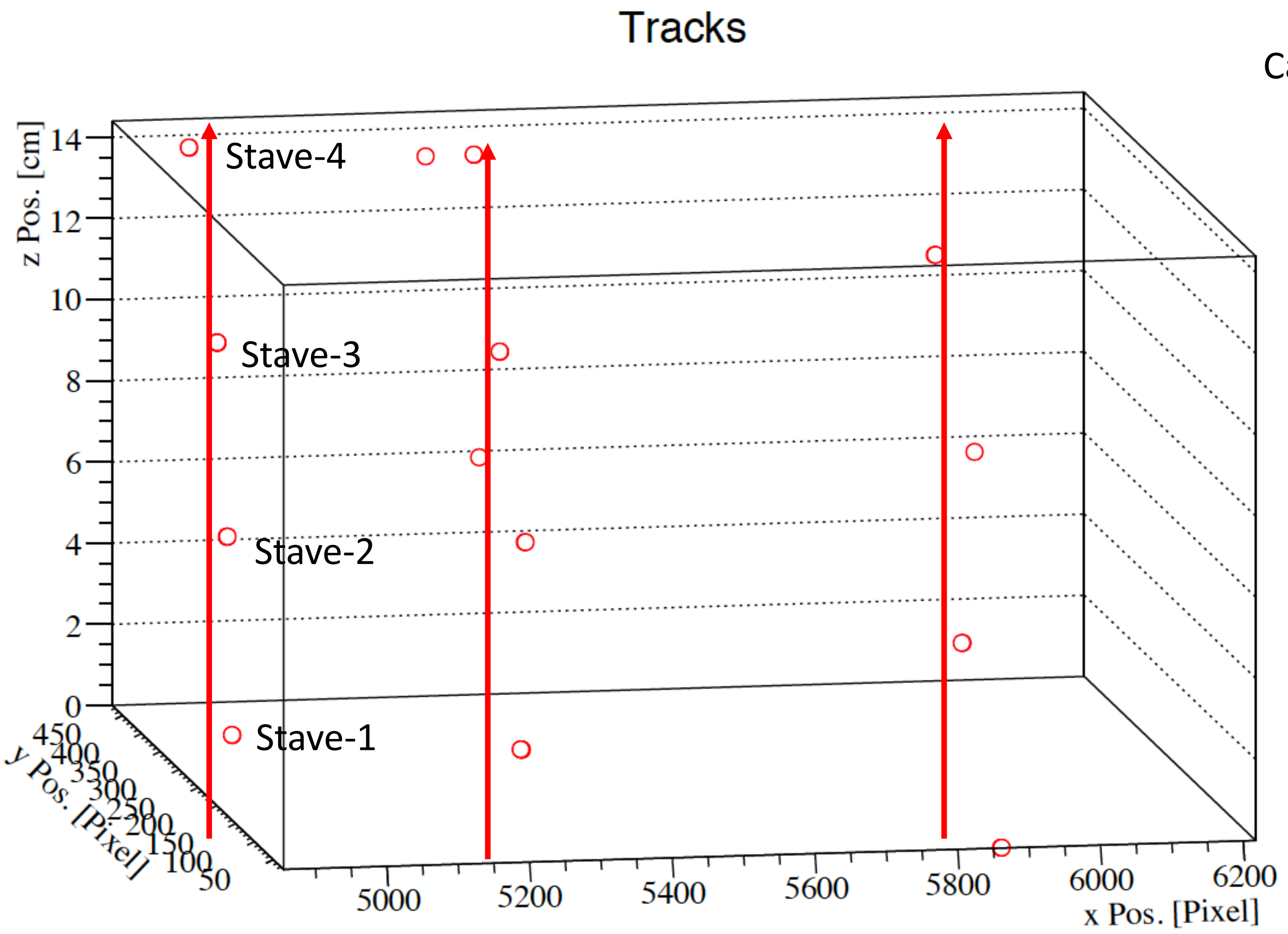
No hits seen when MAPS parameters far-off the optimal point



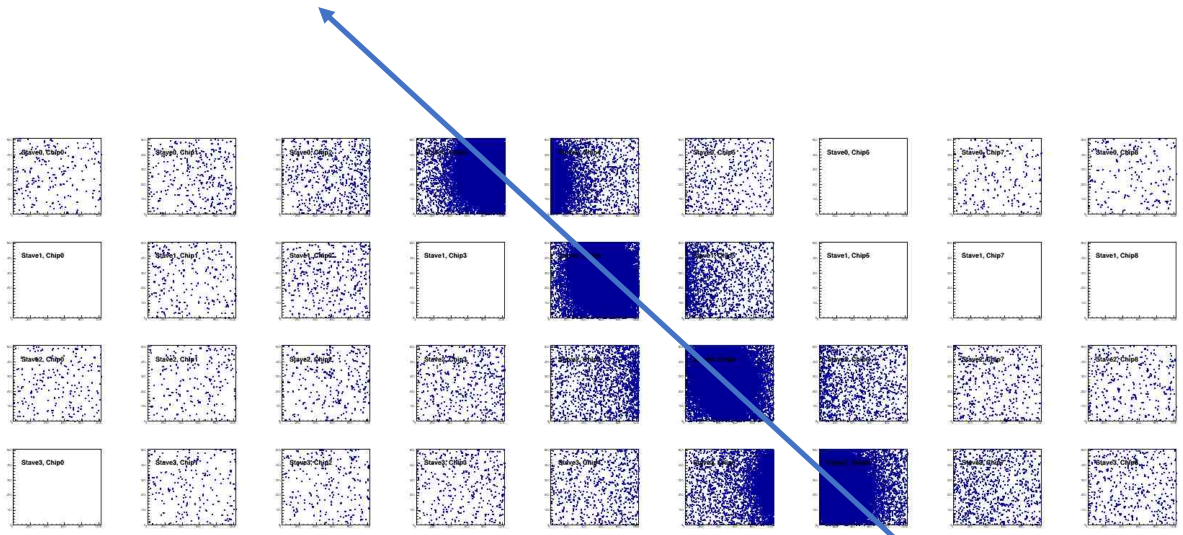
Installation

3-D event Display: p+Pb collision

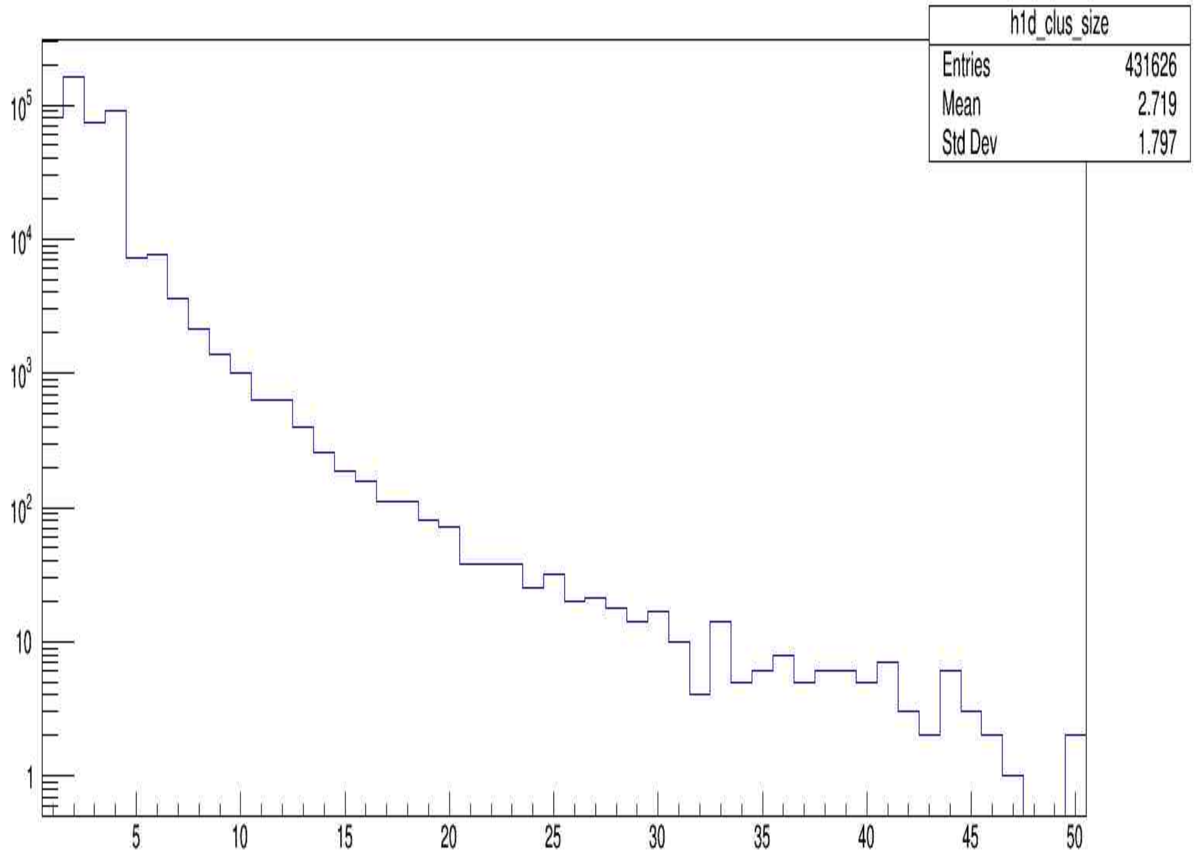
Cameron



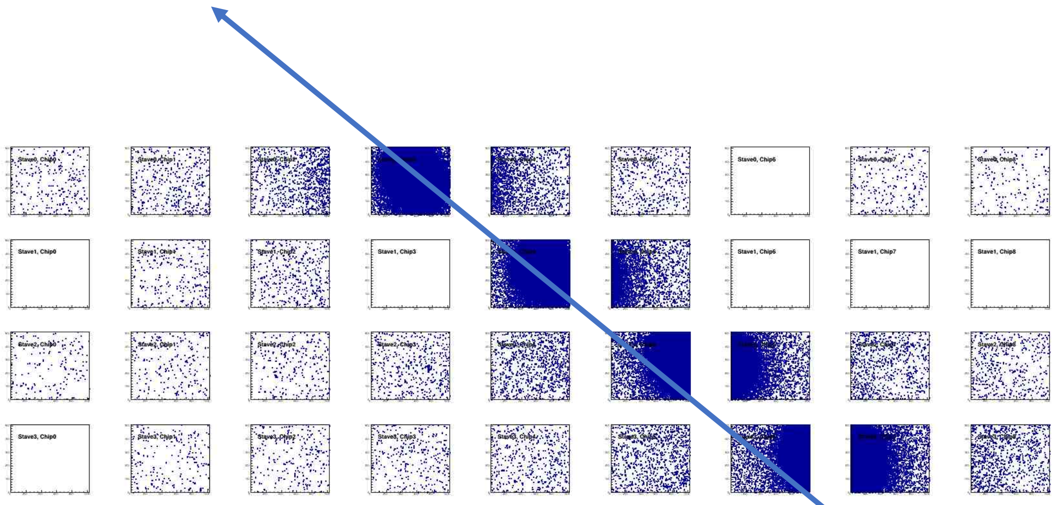
Offline Analysis: Cluster size vs Angle Run 877, angle – 30 dgr



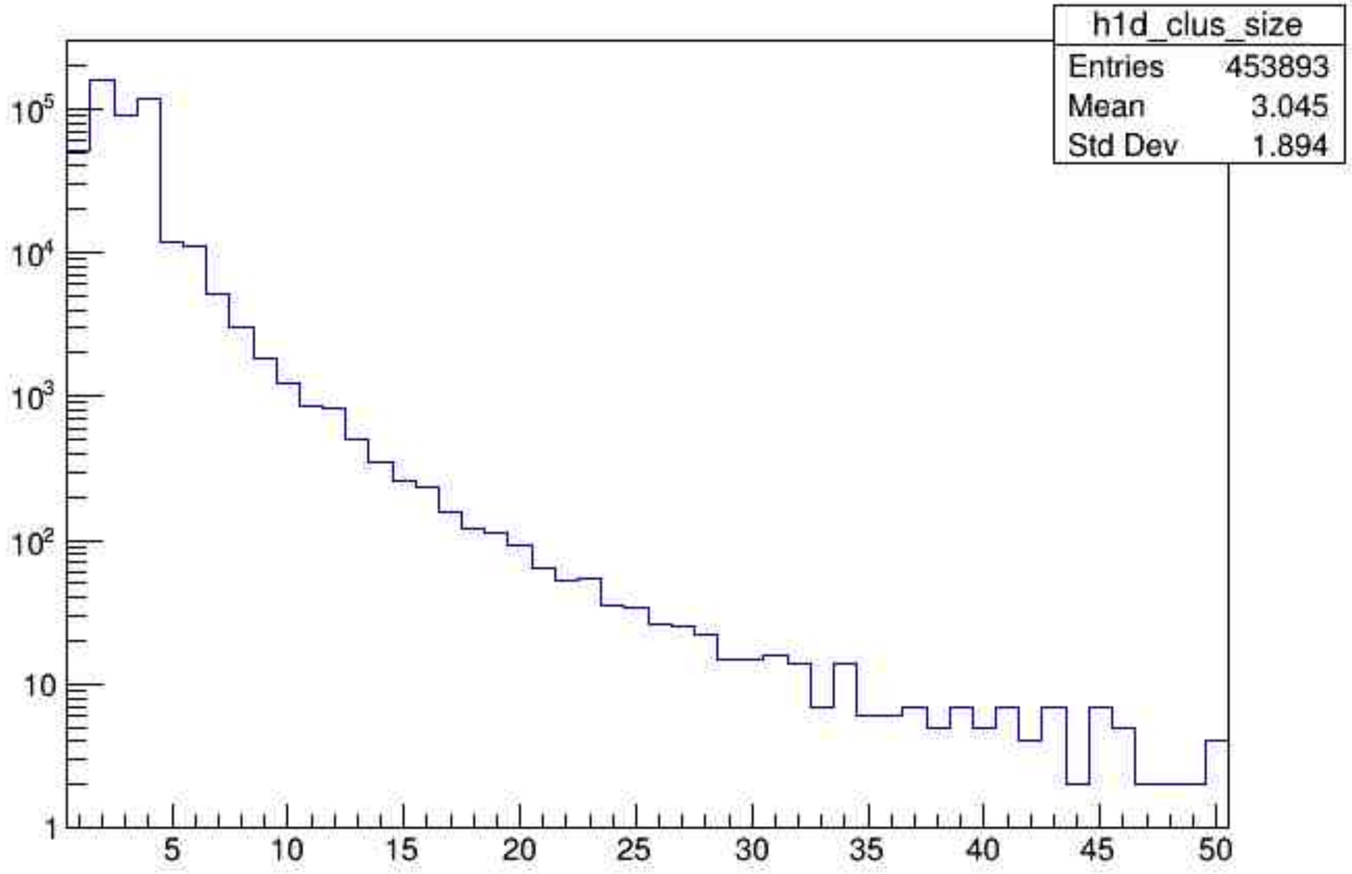
Cluster Size = 2.7



Offline Analysis: Cluster size vs Angle Run , angle = 40



Cluster Size ~ 3.0



More work follows by Yasser, Sanghoon et al
Everyone is welcome to join the effort!

- Stave geometry
- Stave alignment
- Clustering
- Tracking
- Update MVTX MC response in GEANT

MVTX – Half Detector