MVTX Overview

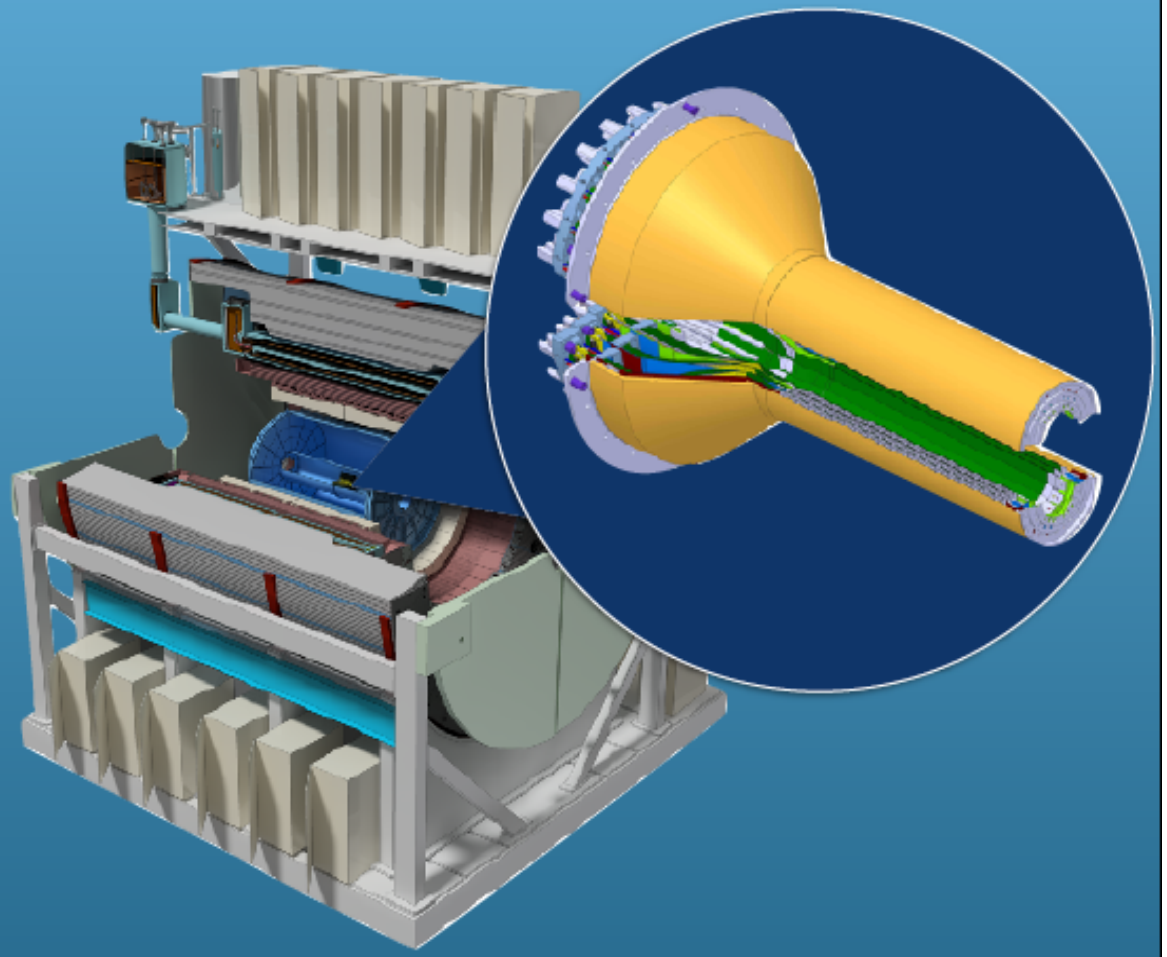
Ming Liu

Pre-QM sPHENIX Collaboration Meeting

November 1-2, 2019

Fudan Univ., China

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

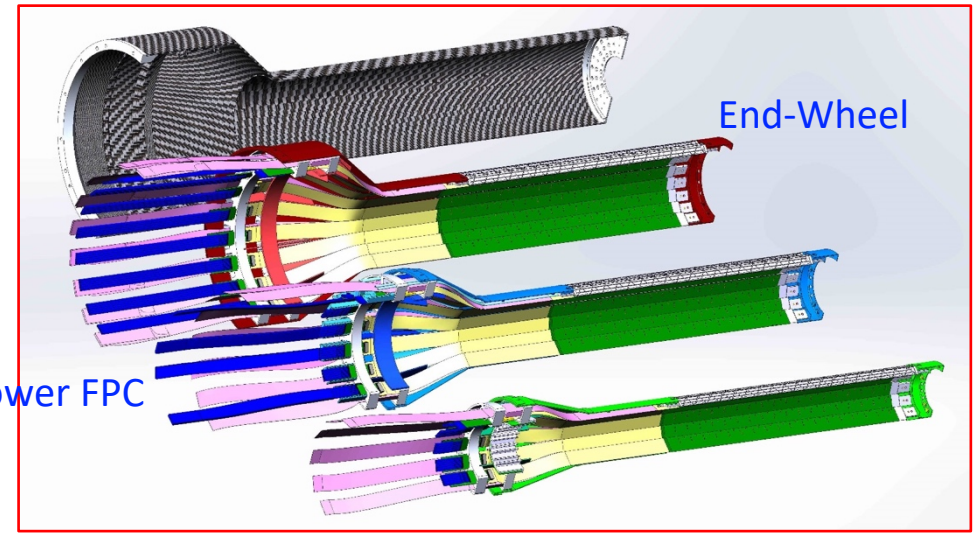


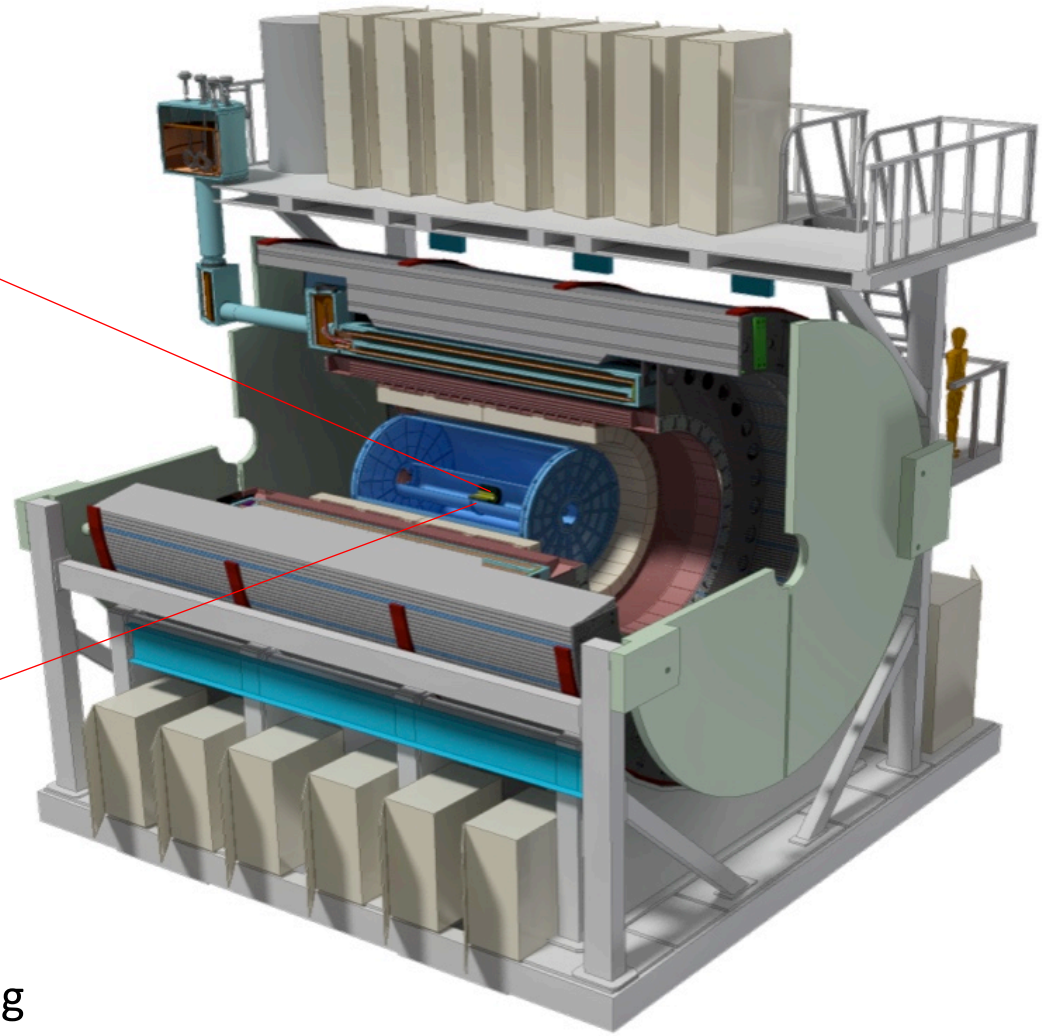
A Monolithic Active Pixel Sensor Detector for the sPHENIX Experiment

MVTX Detector

Service cone: signal, power, cooling
and mechanical support

CYSS: Cylindrical Shell Structure





MVTX parameters

	R_min (mm)
Layer 0	24.61
Layer 1	31.98
Layer 2	39.93

3-layer sensor barrel
- 48 staves, 27.1cm long
- 432 chips

Scope of the MVTX Project – WBS 3.02

- Mechanical system (3.02.03, 3.02.04)
  - MVTX detector mechanical structures
    - Design & simulations
    - End Wheels
    - Cylindrical support structure
    - Service barrels
  - Mechanical system integration
    - Service barrel support & interface to sPHENIX
    - Installation tooling etc.
    - Adopt ALICE cooling parameters
    - Detector safety
  - Detector assembly
    - Stave QA & detector assembly @LBNL
- Electronics (3.02.02)
  - Readout Integration
    - RU QA & assembly @UT-A
    - Backend: ATLAS FELIX production
    - FELIX boards test @LANL/BNL
    - Frontend RU services: daughter cards, transition boards, cables etc.
  - Ancillary systems - “adopt” ALICE ITS system
    - Power, slow control & monitoring etc.

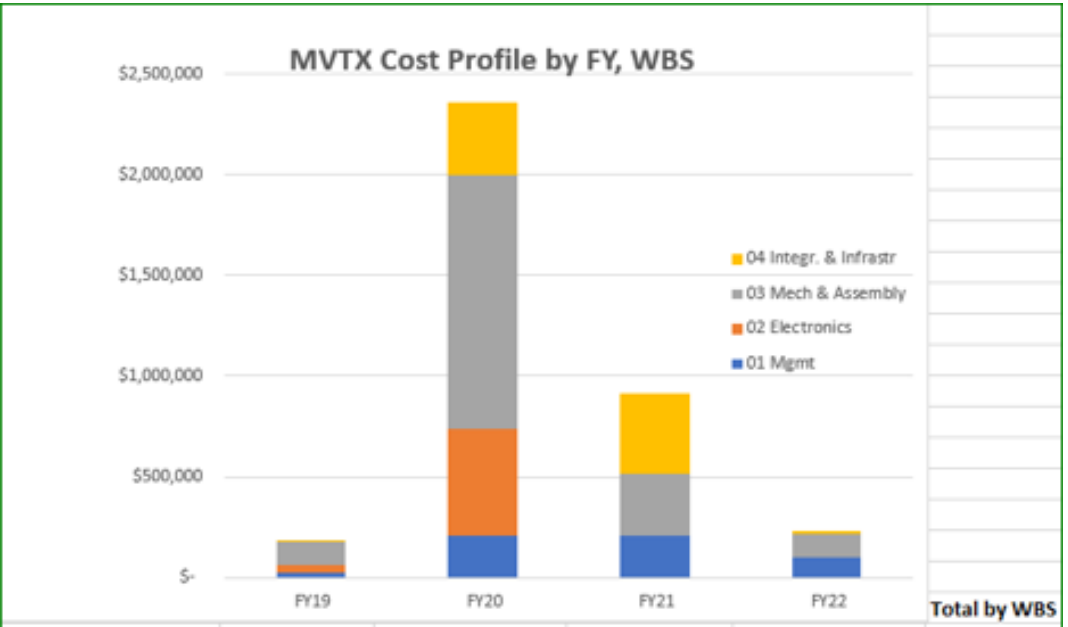
A separate BNL R&D project, provides Staves & RUs
- no cost to MVTX project
- 84 ALICE/ITS-IB (modified) staves from CERN;
  48+spares(2-inner layers+10%), in production
- 60 ALICE/ITS-RU from CERN
  48+spares(12, 25%) , all produced

Project Status Update: 11/01/2019

- Confirmed long SamTec readout cables recently – last key electrical integration hardware R&D
  - 11.4m long cables, > 10m desired length
- MVTX mechanical design: excellent progress
  - Obtained quotes from outside companies based on preliminary designs for CYSS and End-Wheels
  - MVTX/sPHENIX integration/insertion workfest , 11/14 @BNL, MVTX/INTT/TPC…
- Early R&D fund released from BNL
  - MVTX mechanical engineering design, MIT/LANL
  - Preparation for Stave and RU acceptance test, LBNL, UT-Austin
- July 2019 MVTX Cost & Schedule Review Response submitted
  - WBS, PMP, Risk Registry, P6 updated
  - Updated PMP and review response submitted to DOE
  - We are ready for full production
- Plan to start the MVTX production activities as soon as funds available
  - Preparation for Stave and RU acceptance test & QA in US, LBNL and UT-A
  - Carbon structure prototype production, site selection etc
- Stave and RU production
  - Stave production in progress at CERN
  - 60 MVTX RUs delivered to CERN
  - Power mezzanine and transition boards produced at UT-A

Funding Profile (FY19+20, 21,22)

From July MVTX Review:



					Total by WBS
01 Mgmt	$ 23,540	$ 210,128	$ 209,596	$ 101,338	$ 544,602
02 Electronics	$ 41,687	$ 527,895			$ 569,582
03 Mech & Assembly	$ 112,831	$ 1,257,896	$ 307,183	$ 113,468	$ 1,791,378
04 Integr. & Infrastr	$ 3,200	$ 364,985	$ 399,262	$ 15,491	$ 782,939
Grand Total	$ 181,258	$ 2,360,904	$ 916,041	$ 230,297	$ 3,688,501

MVTX funding profile: FY20 -22

sPHENIX MVTX Budget Profile				
	FY20	FY21	FY22	Total
3.02.01 Management	$233,668	$209,596	$101,338	$544,602
3.02.02 Electronics	$569,582			$569,582
3.02.03 Mechanics and Assembly	$1,370,727	$307,183	$113,468	$1,791,378
3.02.04 Integration and Infrastructure	$368,185	$399,262	$15,491	$782,938
Performance Measure Baseline	$2,542,162	$916,041	$230,297	$3,688,500
Contingency	$762,649	$274,812	$69,089	$1,106,550
Total Project Cost	**$3,304,811**	**$1,190,853**	**$299,386**	**$4,795,050**

Can we move some FY20 ($3.3M) activities to FY21 ($1.2M), with minimal impact to the project?

Schedules – Smooth Funding Profile?

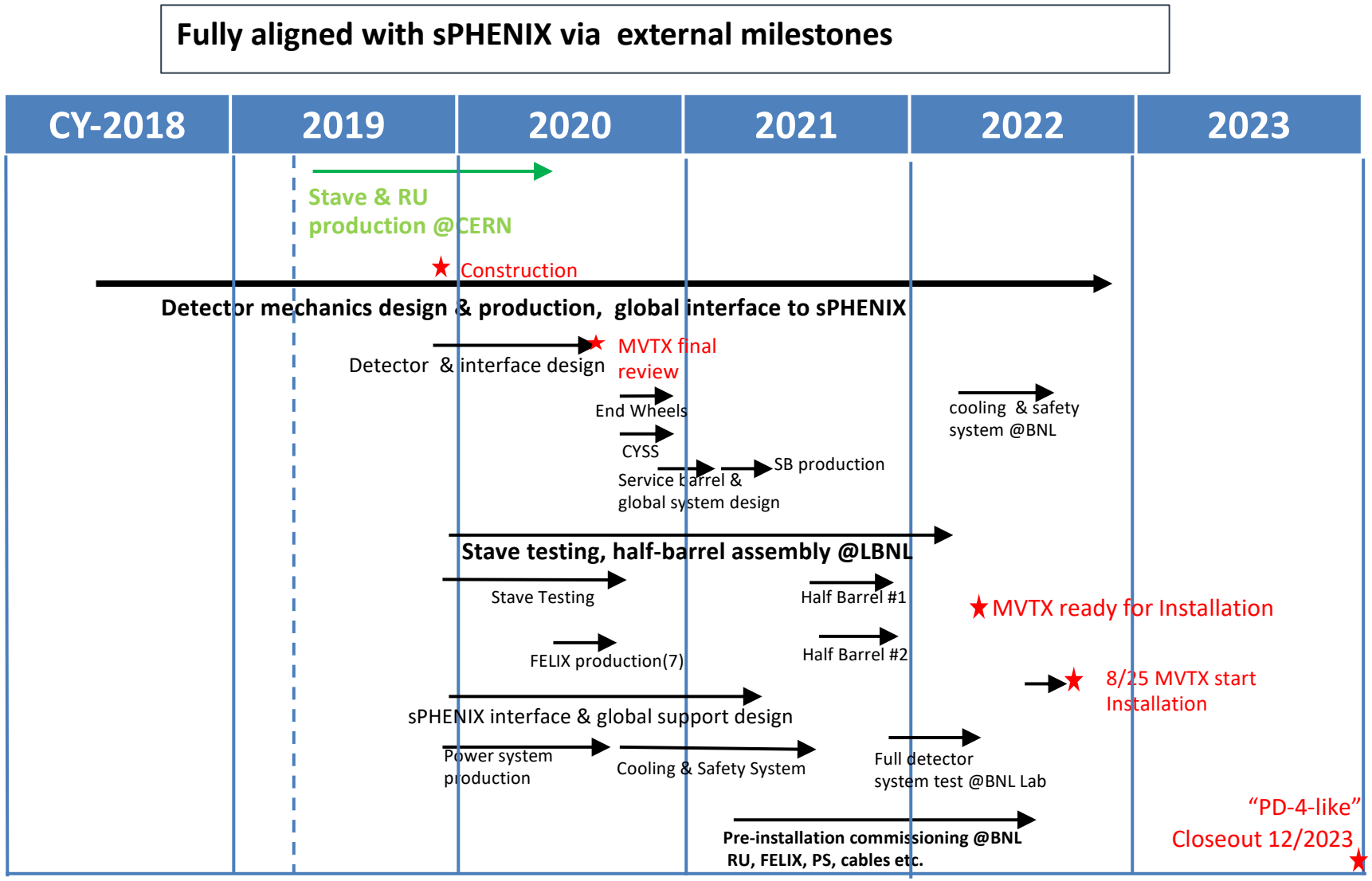
Possible Plan-B for FY20?

Candidates for possible delays, from FY20 to FY21:

- Carbon Structure production
- PU and CAEN PS
- Cooling system
- Delay stave test and detector assembly work at LBNL

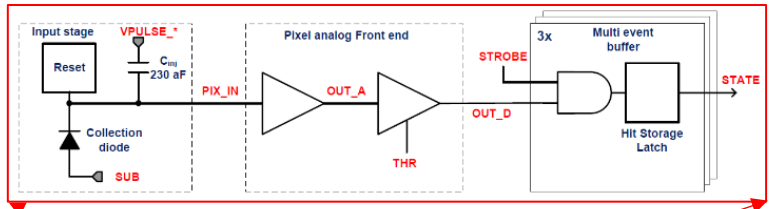
Recent new quotes for carbon structures: CYSS & EndWheels

- Possible cost saving through commercial companies
- Carbon structure full production possible in FY20, w/ big saving

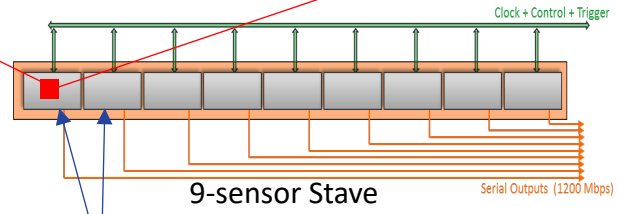


MVTX Readout, Power and Controls Hardware Tested

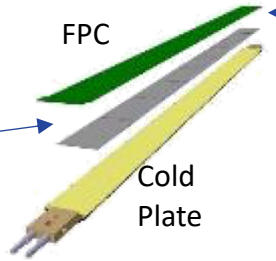
Hardware status: Staves in production; RU produced, SamTec, PU & FELIX ready for production



one pixel



9-sensor Stave



Alpide Sensors

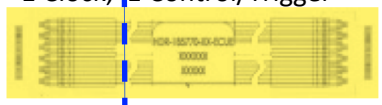
FPC

Cold Plate

Power

Flex PCB Filtering Capacitors

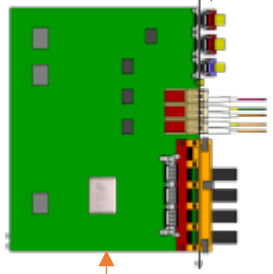
9 Data (1.2Gbps)
1 Clock, 1 Control/Trigger



Samtec Twinax "FireFly", ~10m

Regulated Power

Readout Unit Front End



regulators

Power Board

Power

CAEN Power supplies

CAN bus

DCS

Trigger & Clock

GBT Optical Links

Control

Data (9.6 Gb/s max)

Trigger

FELIX Back End

Interaction Region | Experimental Hall | Counting House

- Slow control Mike's talk

ATLAS Front-End Link eXchange (FELIX):

- sPHENIX Data Aggregation Module(DAM)

ALPIDE pixel:

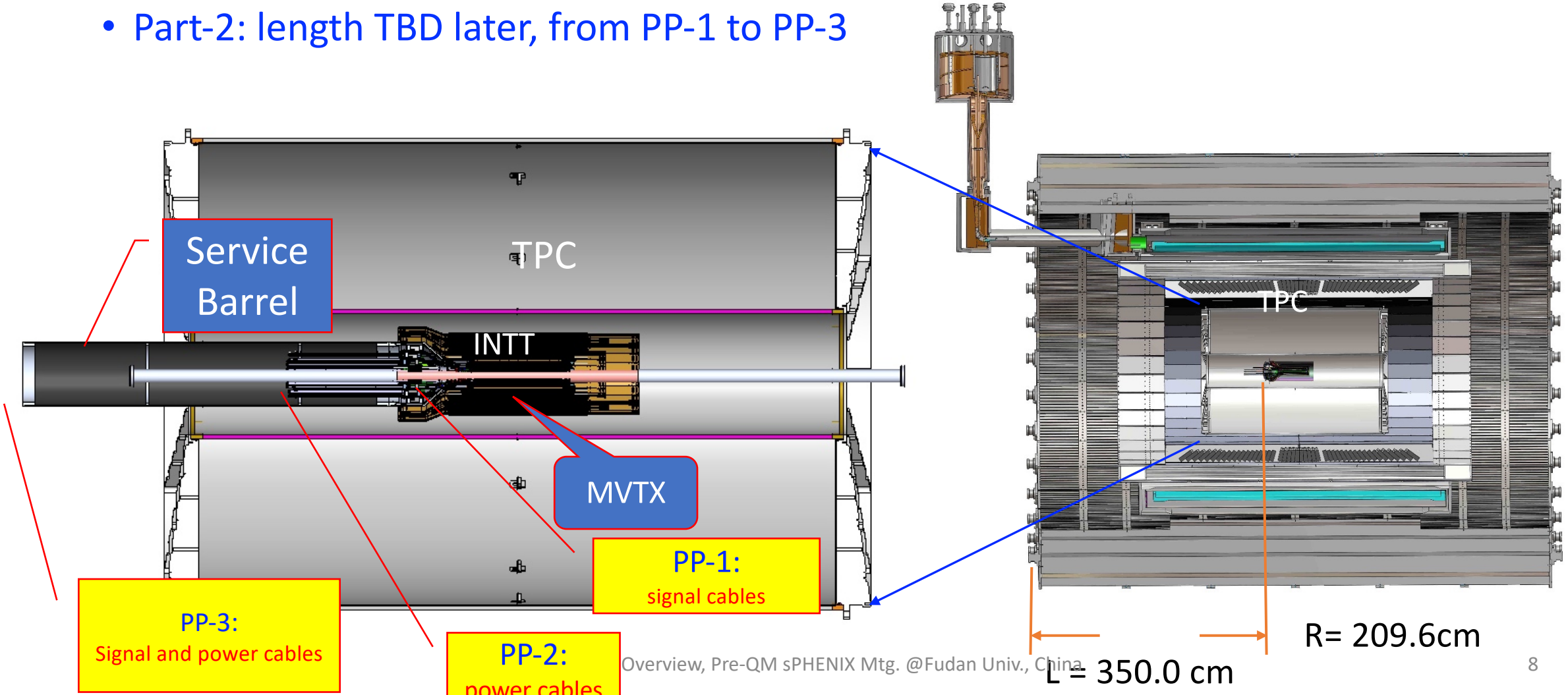
- Shaping
- Digitization
- Zero-suppression
- 3x buffer

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

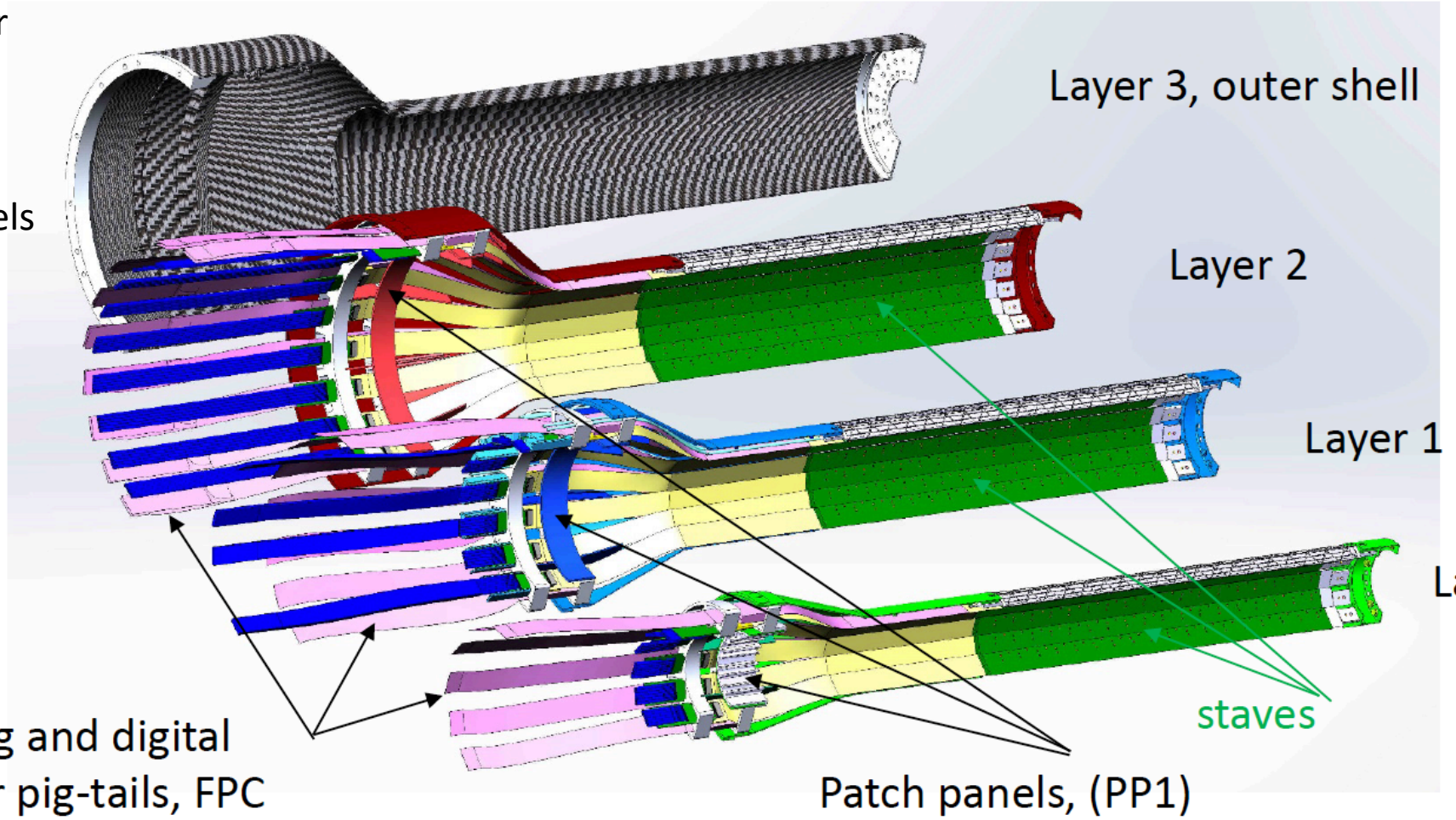
- MVTX mechanical system preliminary design:
  - Part-1: from MVTX staves to PP-1, all power PCB, 40cm
  - Part-2: length TBD later, from PP-1 to PP-3



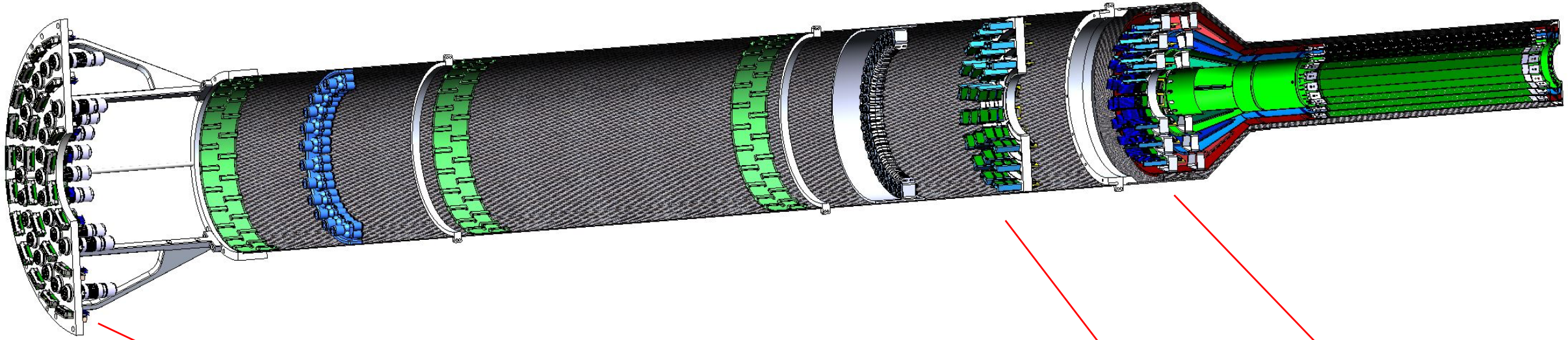
Detector Supporting Structures: Part-1

- Near final design completed for CYSS, End-Wheels
- Obtained quotes from outside companies based on the latest designs for CYSS and End-Wheels
- LBNL cost estimate in progress

Next:
- Vendor selection
- Pre-production



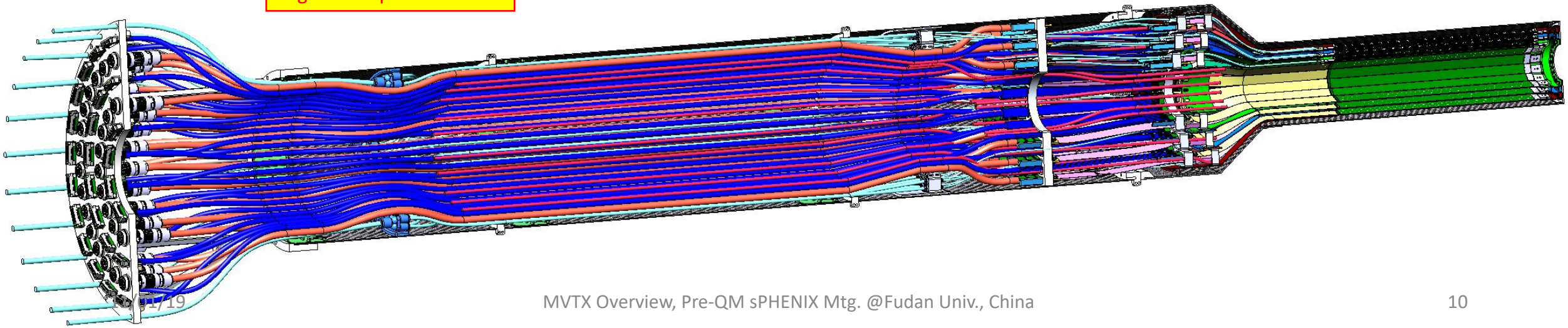
MVTX Service Barrel – Part-2



PP-3:
Signal and power cables

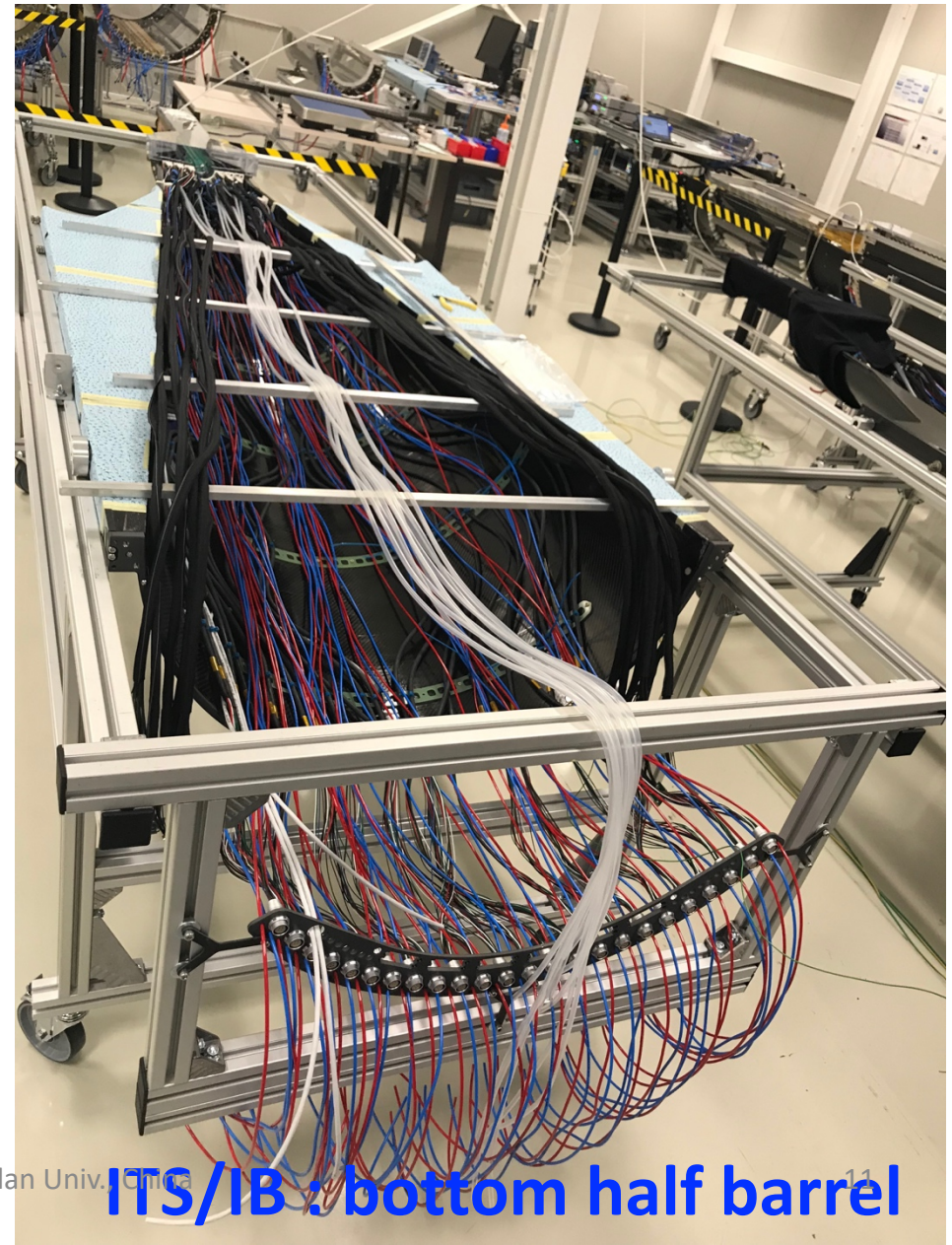
PP-2:
power cables

PP-1:
signal cables



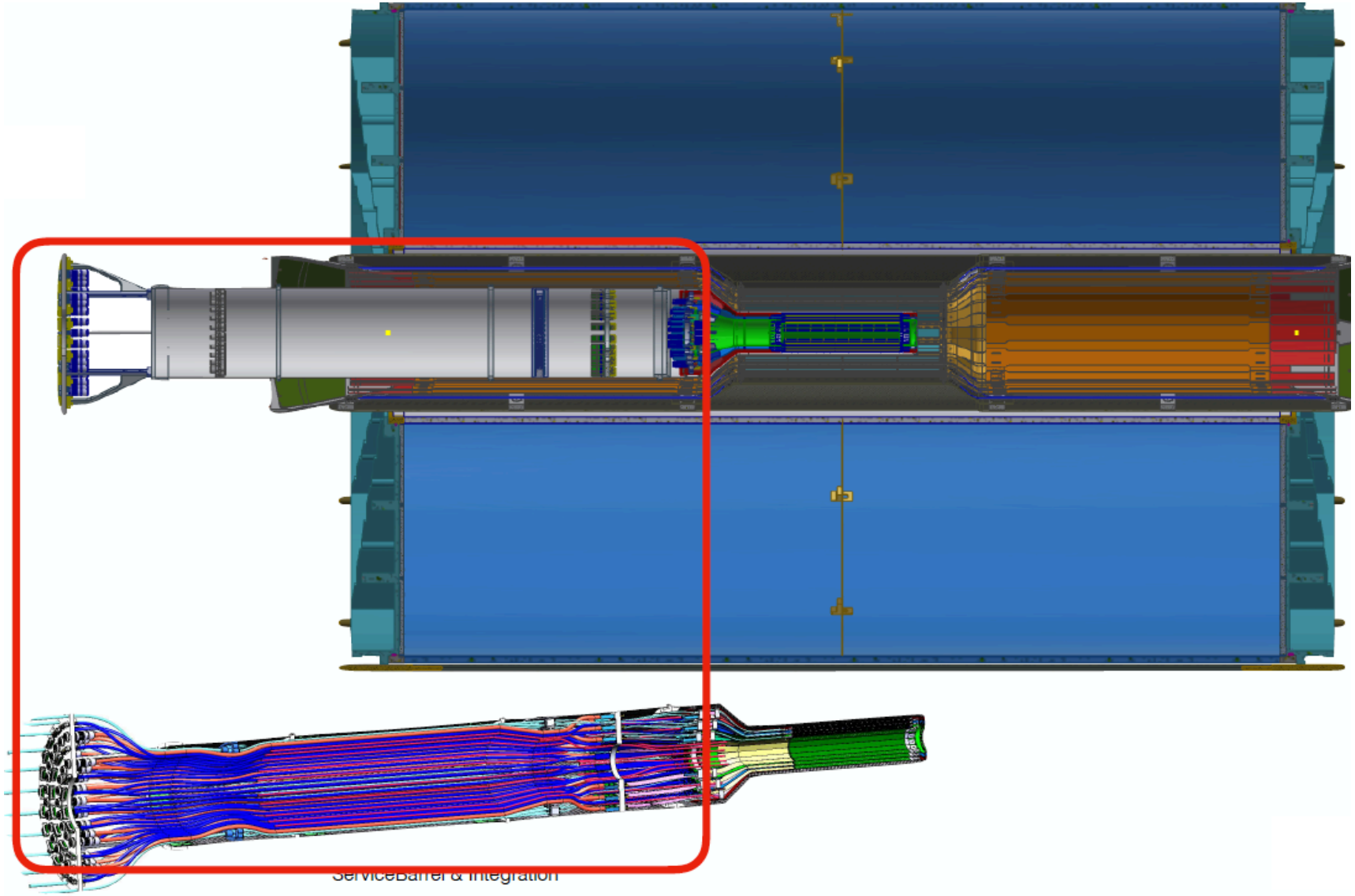
ITS/IB Commissioning Setup @CERN, 9/2019

ITS/IB : top half barrel



ITS/IB : bottom half barrel

MVTX Global Mechanical System Integration



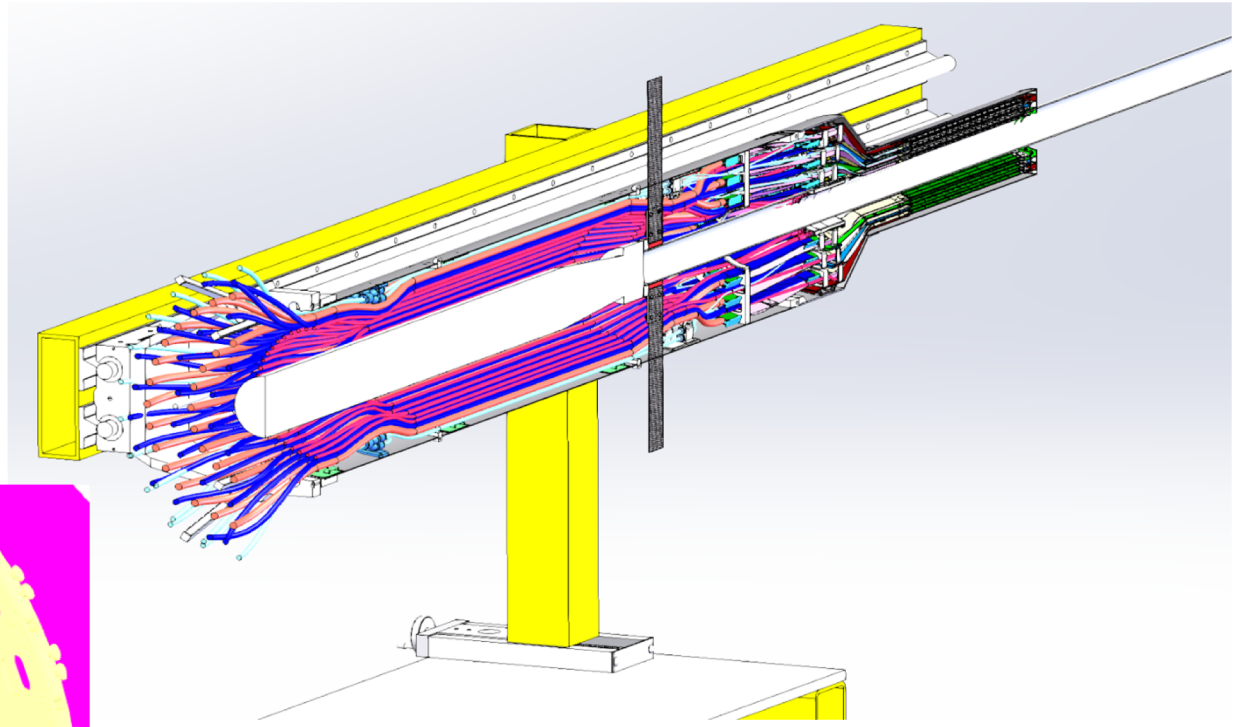
MVTX Installation & Insertion System

(WBS 2.x)

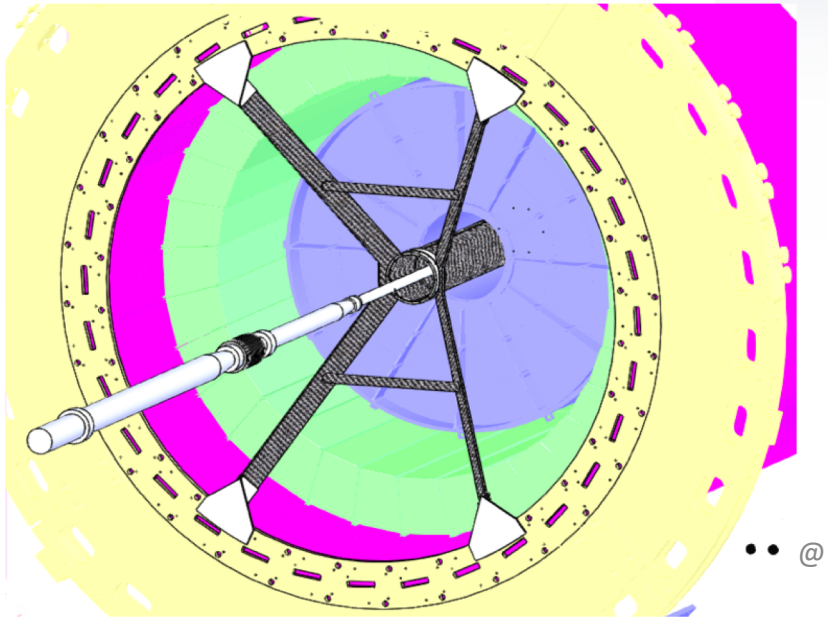
- Active discussions on mechanical design and fabrications
  - MIT, LANL, LBNL
  - CYSS, End-Wheels, Service Barrel

One-day MVTX/sPHENIX insertion system workshop 11/14/2019@BNL, Russ/OSI, Camelia et al

- MVTX, INTT, TPC …



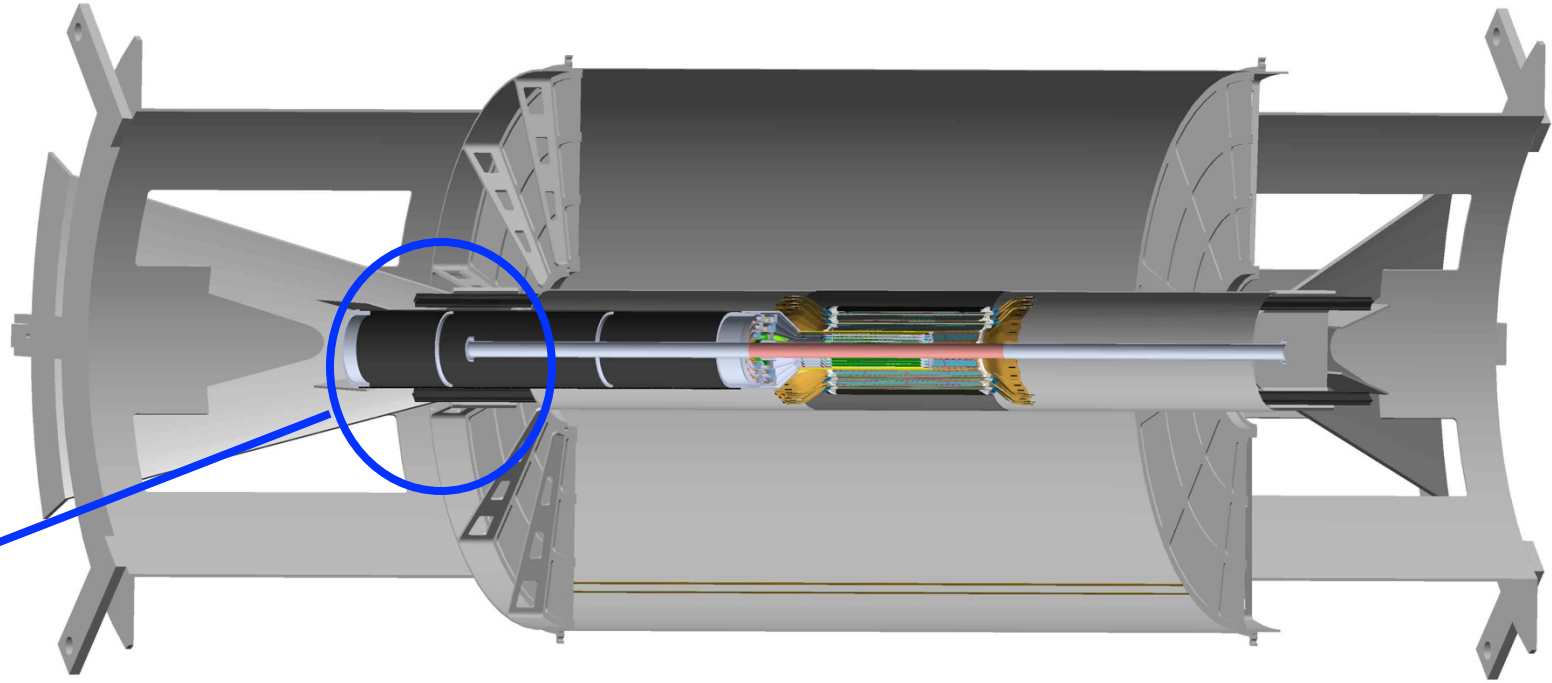
MVTX Installation Mockup

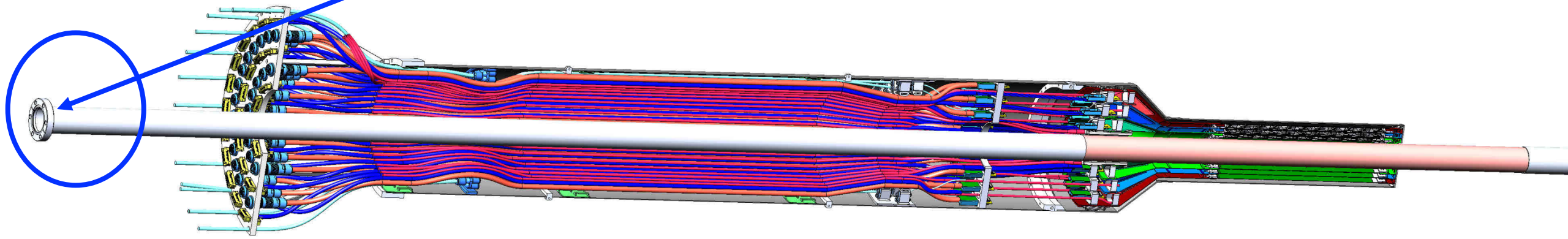


Beam Pipe Extension by CAD

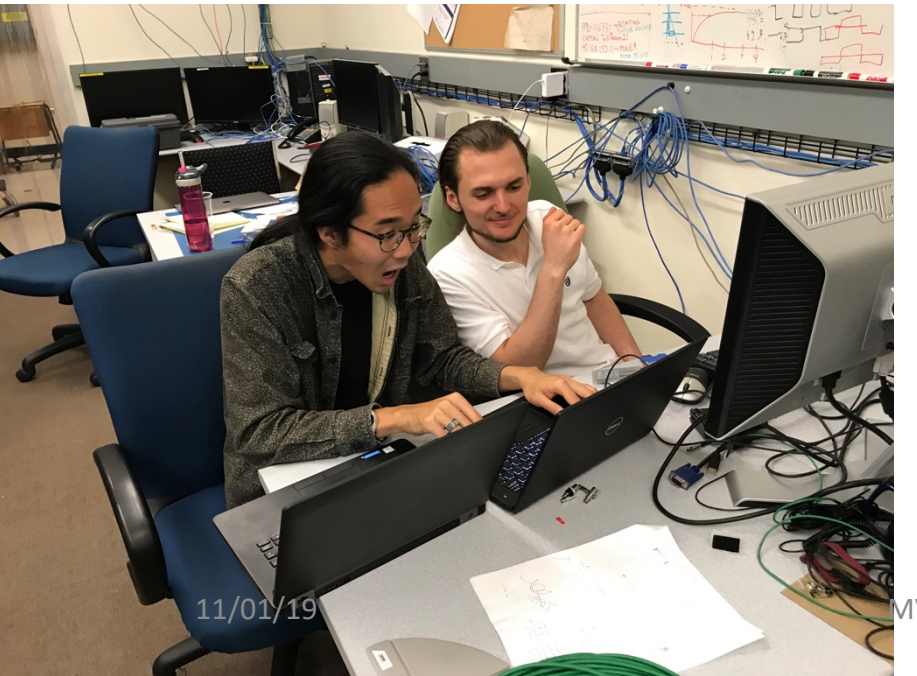
(WBS 2.x)

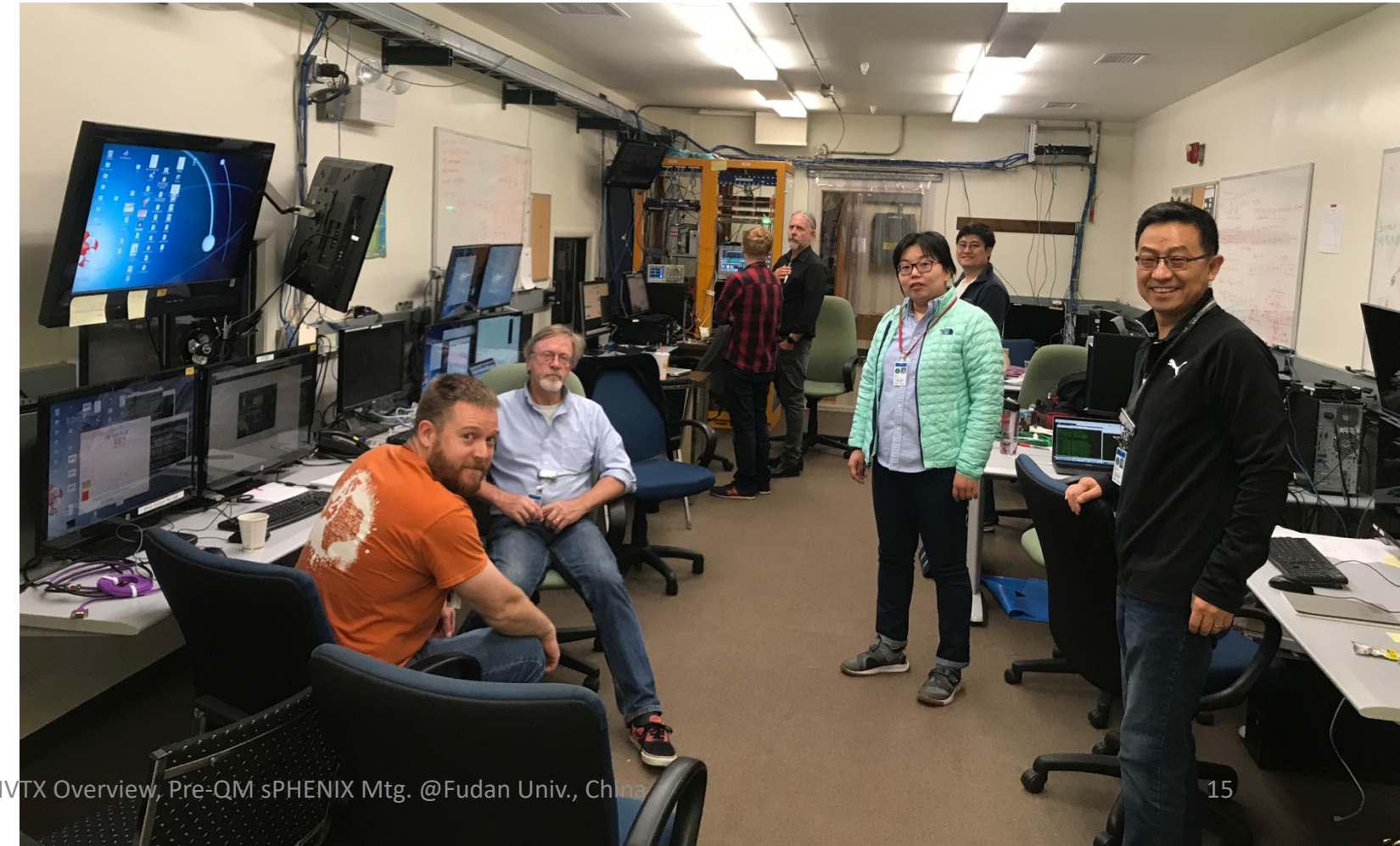
- sPHENIX engineers meeting regularly with the CAD vacuum group;
- CAD will do some test welds to beam pipe material of the same OD to confirm;
- Beam pipe modification in the MoU with CAD.





2019 Fermilab Test Beam Highlights

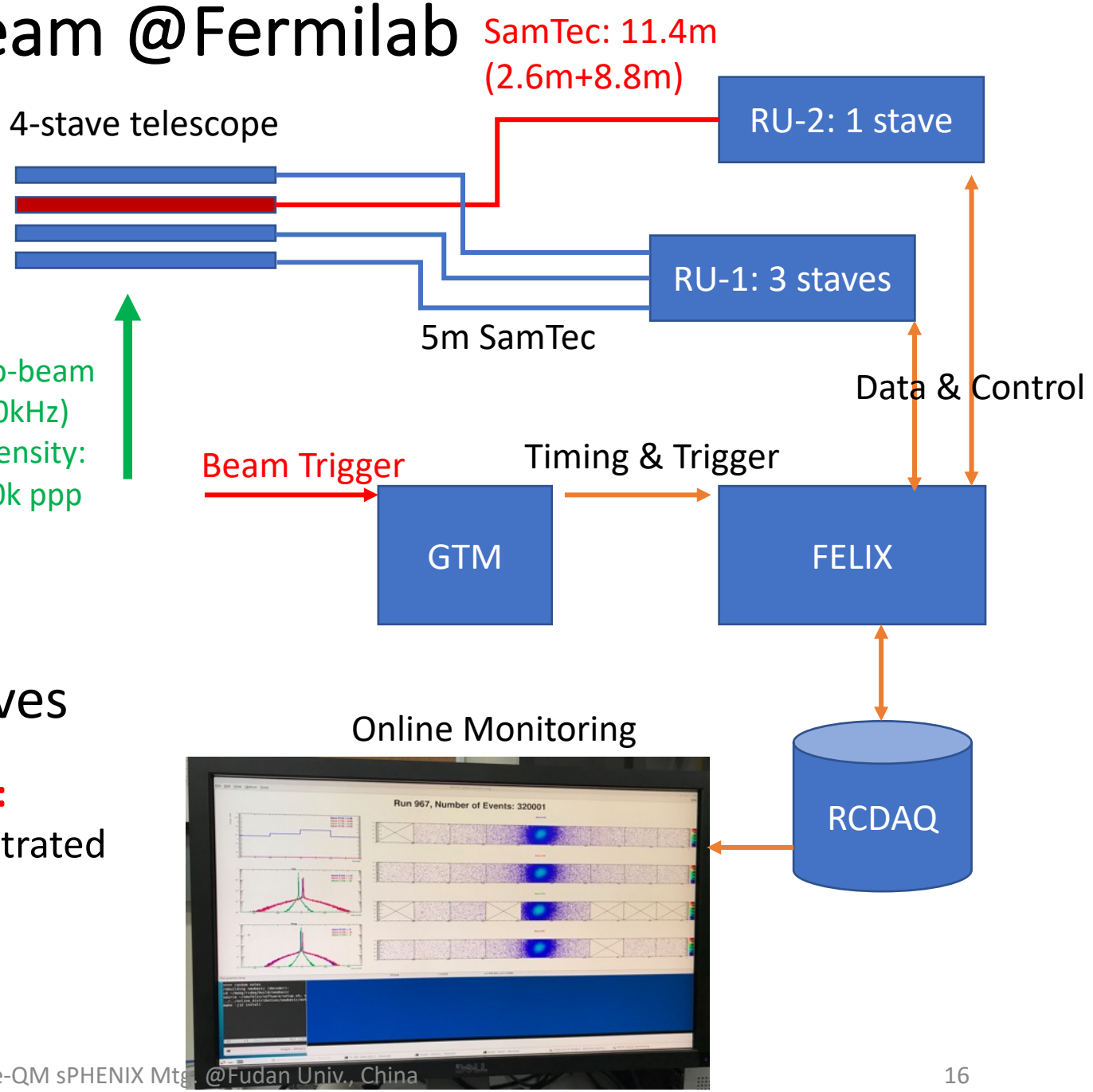




Very Successful Test Beam @Fermilab

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

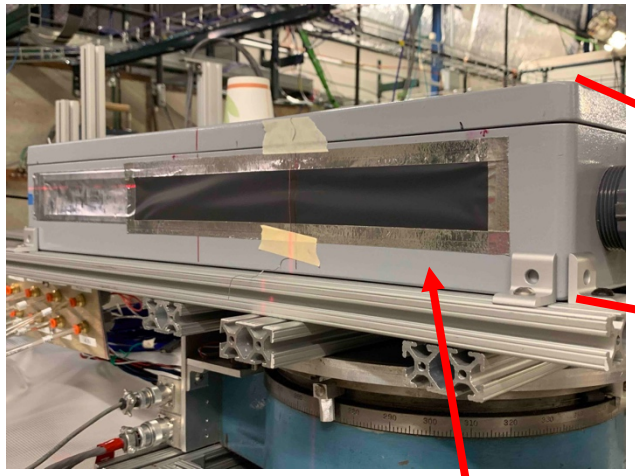


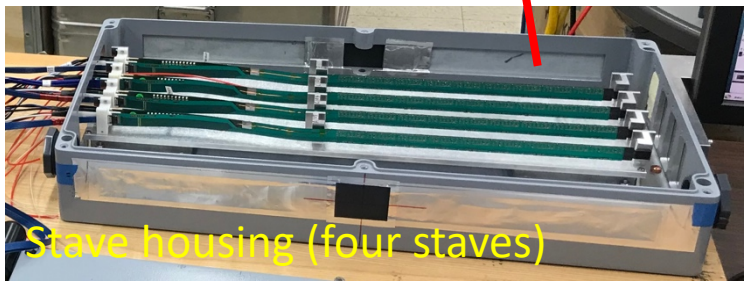
A full system with final sensor/readout* hardware:

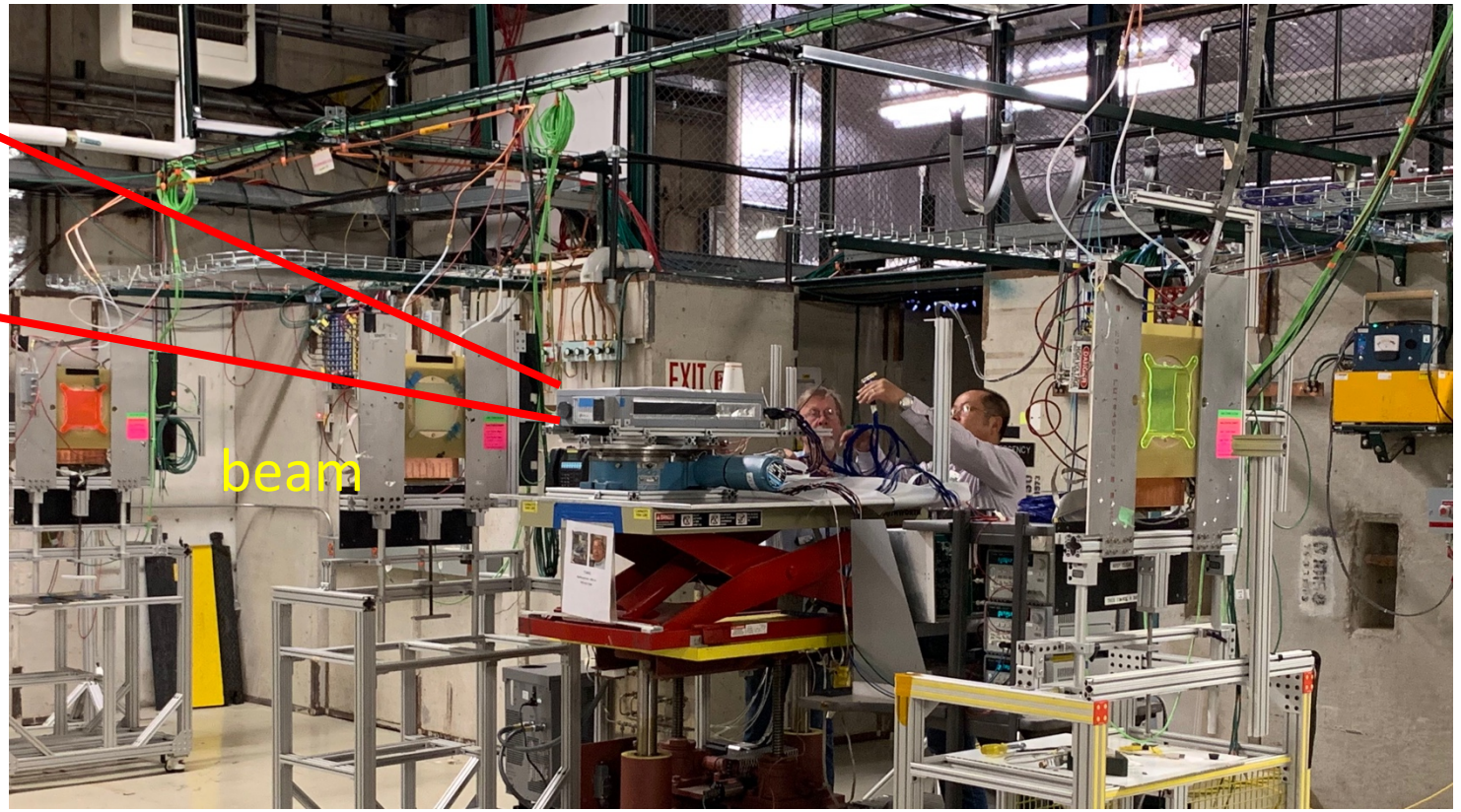
- Multi-Stave + Multi-RU -> FELIX readout demonstrated
- sPHENIX GTM integrated
- Long readout SamTec cable certified
- Cooling system demonstrated

* RUv1.1 identical to the final RUv2 electrically

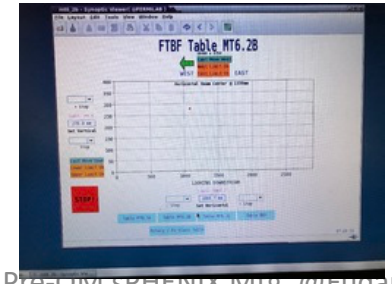
2019 MVTX Test Setup

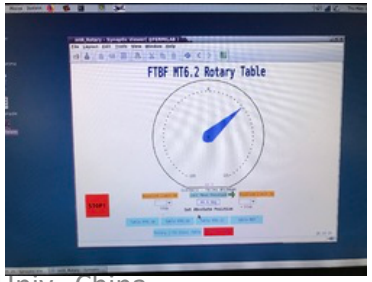






Stave housing sits on a motion table which can be moved in (x, y) plane perpendicular to the nominal beam direction. It can also be rotated (+40, -40) degrees (see photo on right). Operation was done at counting house.



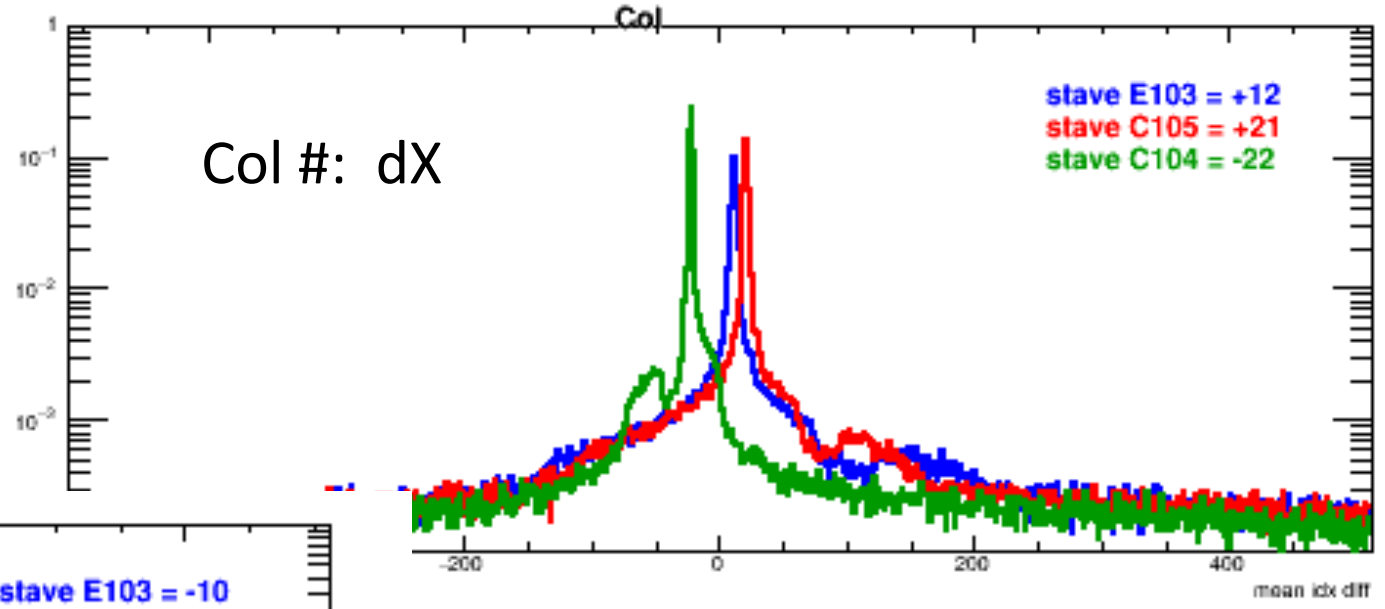


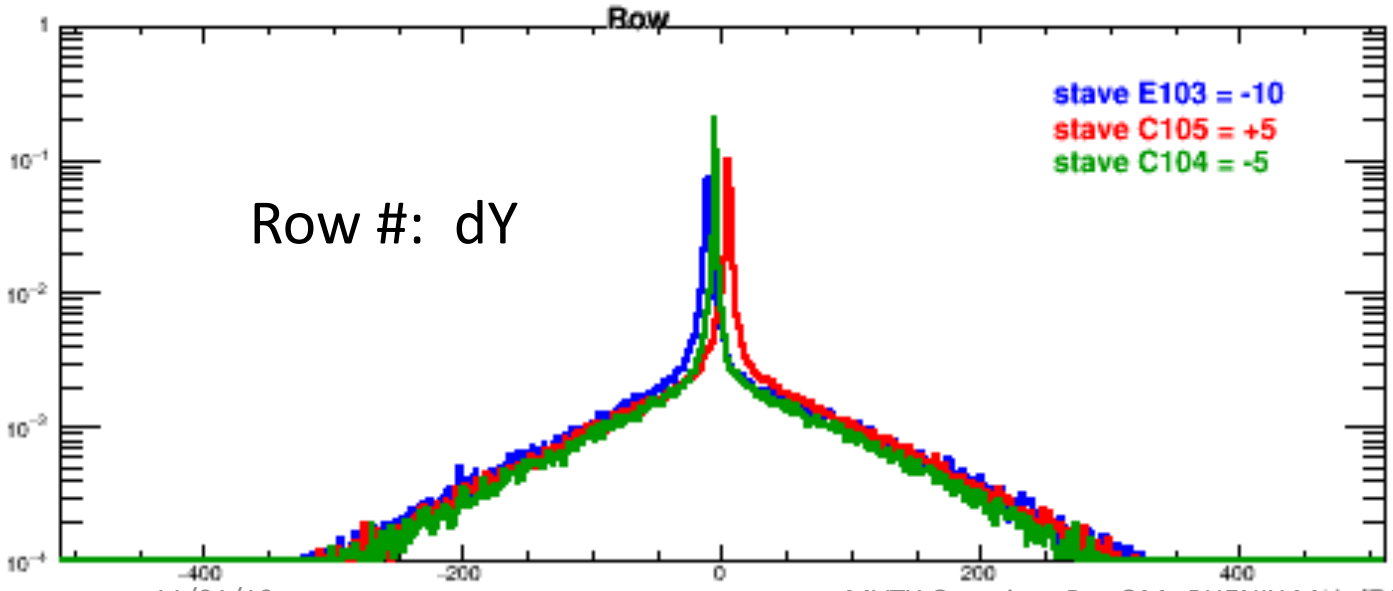
Online Analysis:
Detector Misalignment & Hit Spatial Resolution

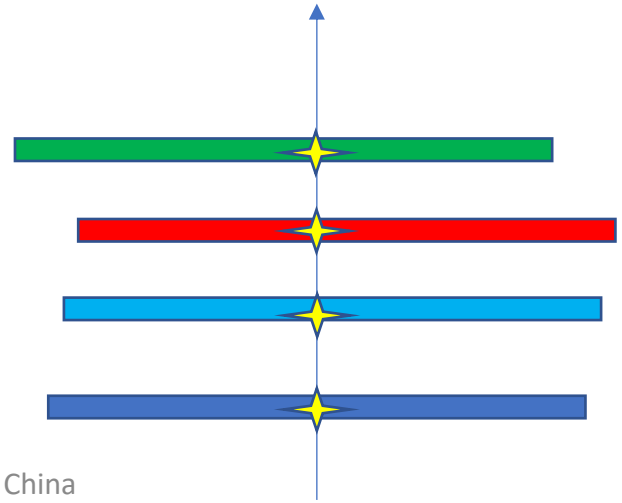
Typical stave offset,
Horizontally: 20 x 30um = 600 um
Vertically: 5 x 30 um = 150 um

Hit spatial resolution:

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



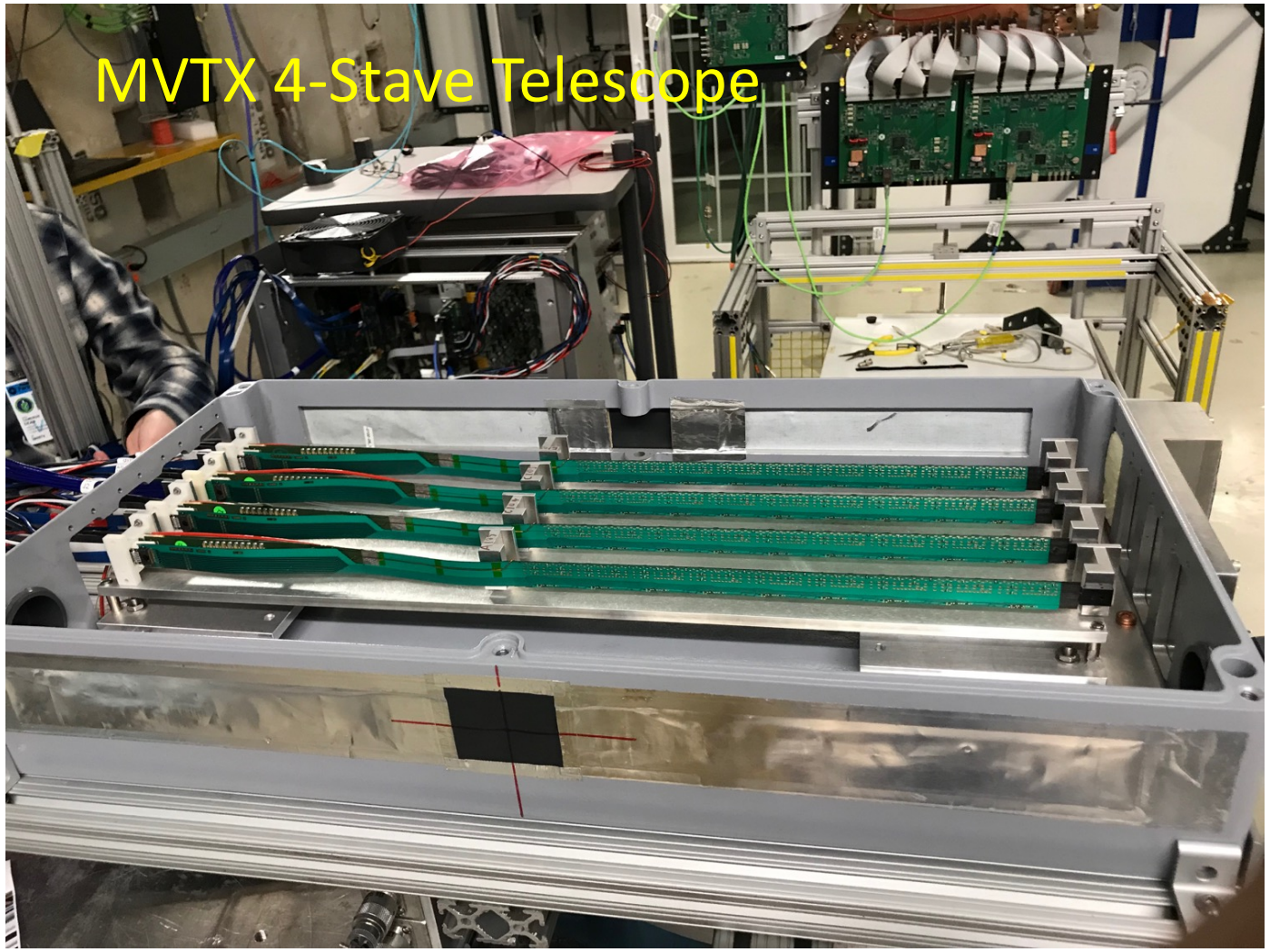




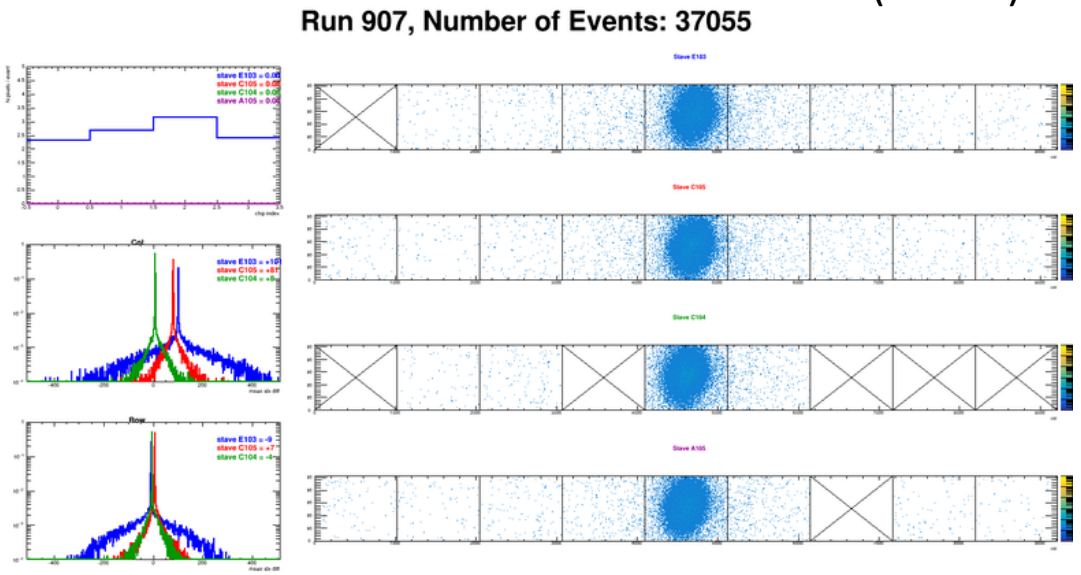
Delta_X/Y

Ref plane

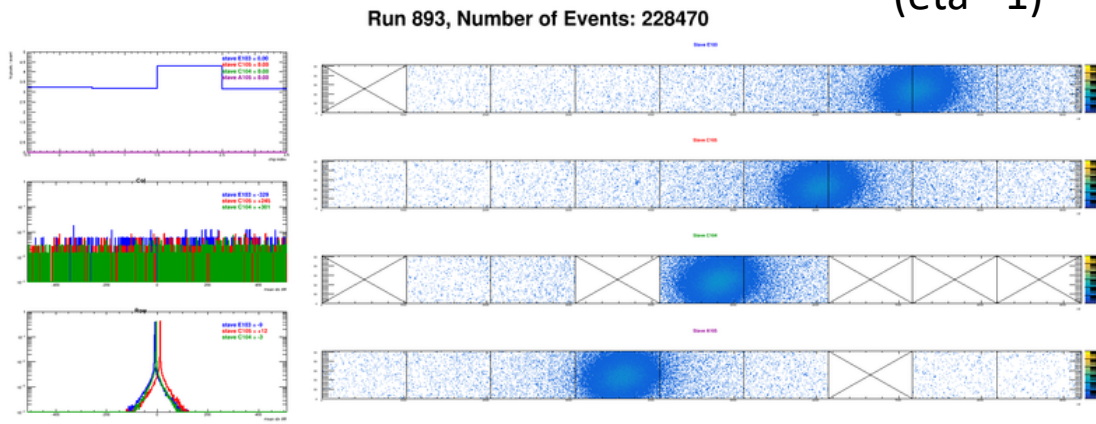
Offline analysis in progress: all TB data in RCF
https://wiki.bnl.gov/sPHENIX/index.php/MAPS-based_Vertex_Detector_(MVTX)



Beam angle: 0
(eta ~0)



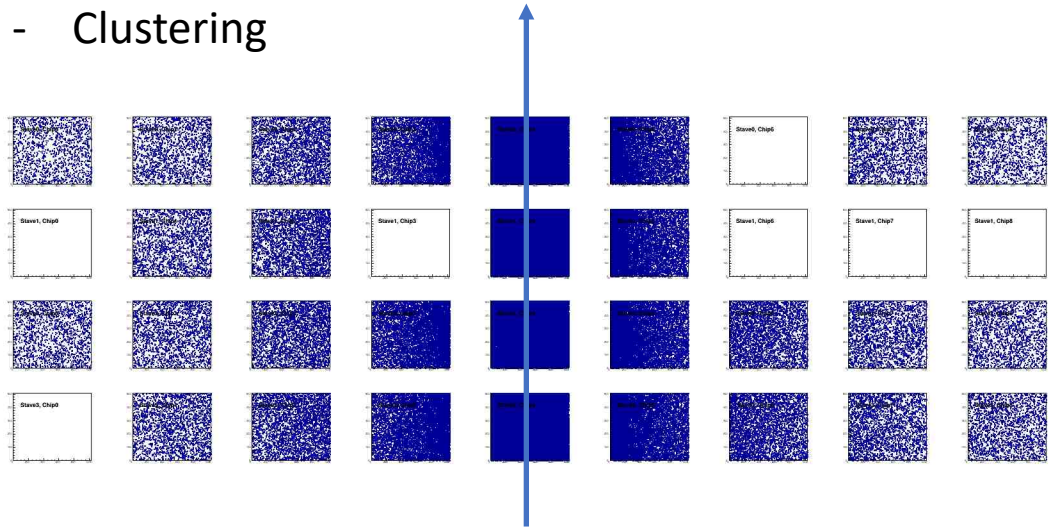
Beam angle: 40
(eta ~1)

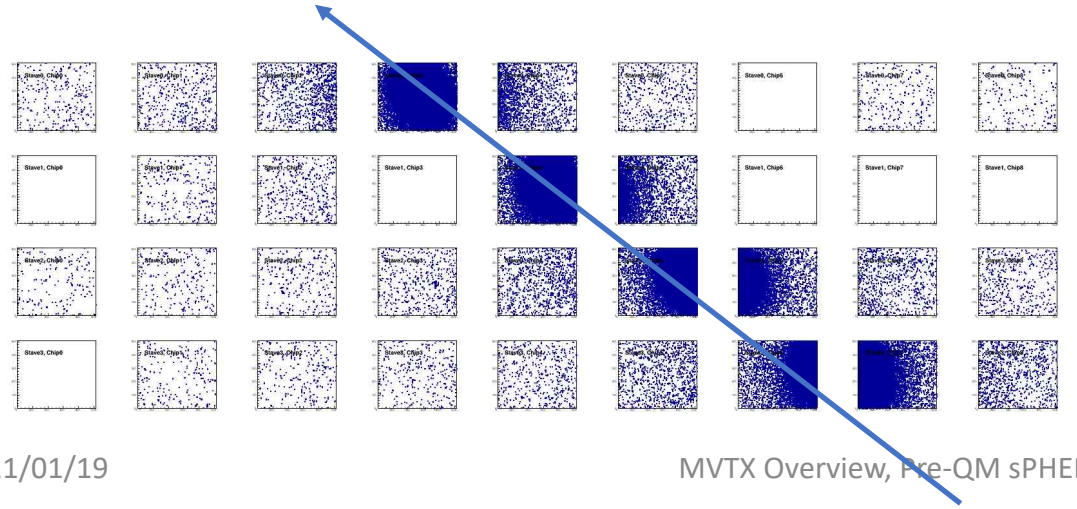


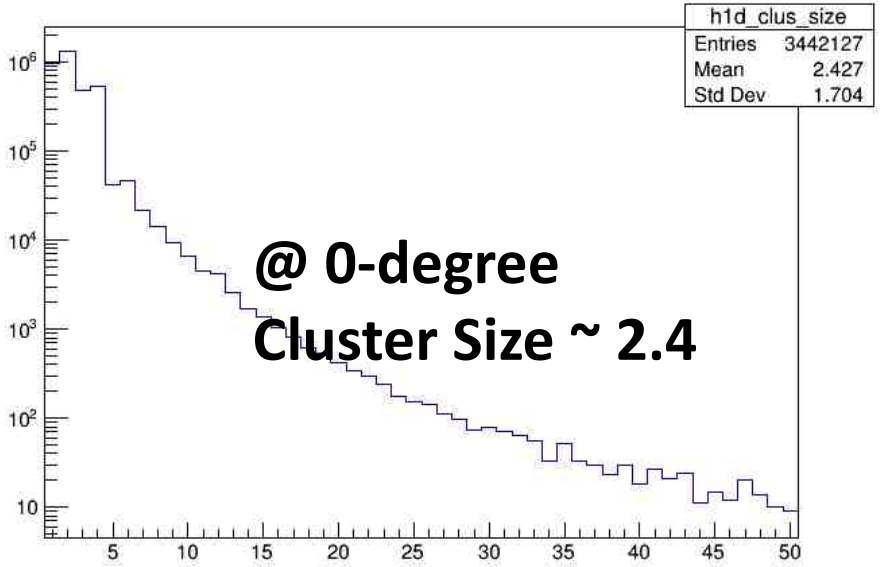
Offline Analysis: Cluster size vs Angle

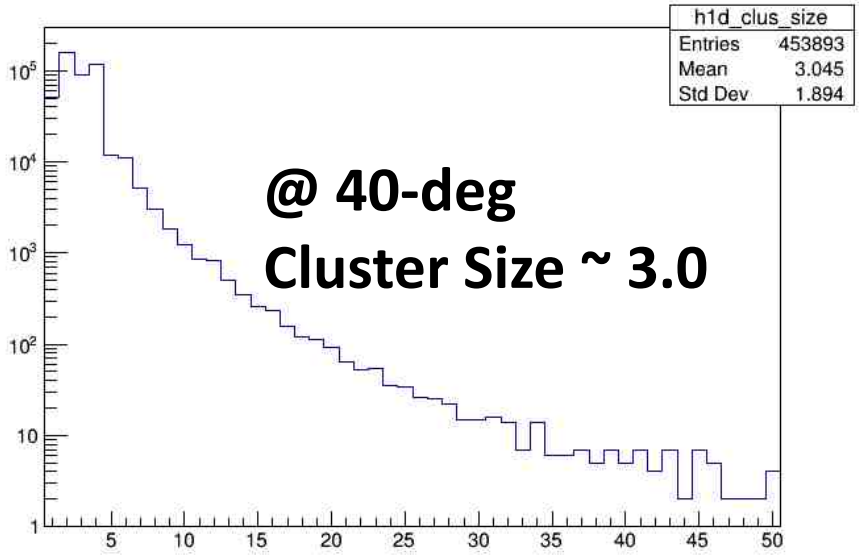
To calibrate MC simulations and tracking

- Stave geometry, alignment
- Clustering



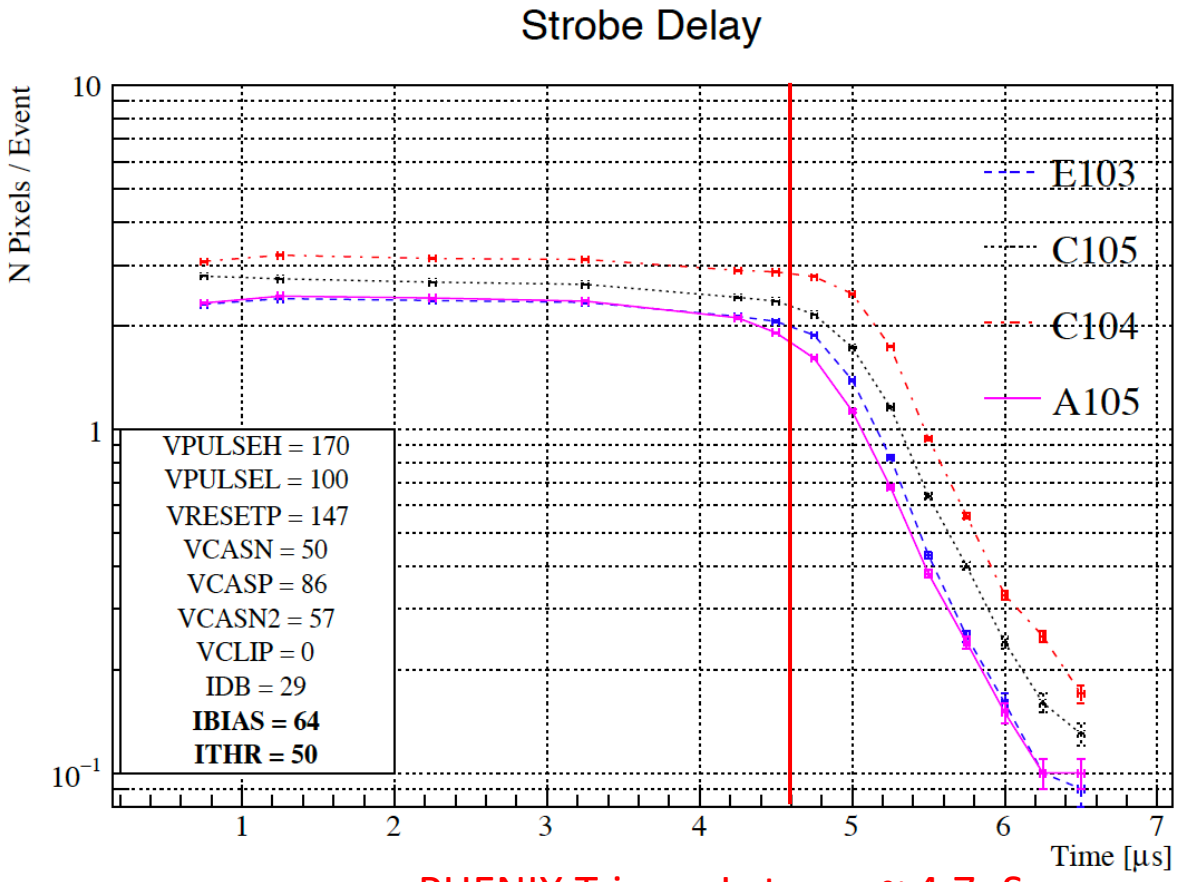






ALPIDE Sensor Operation Optimization

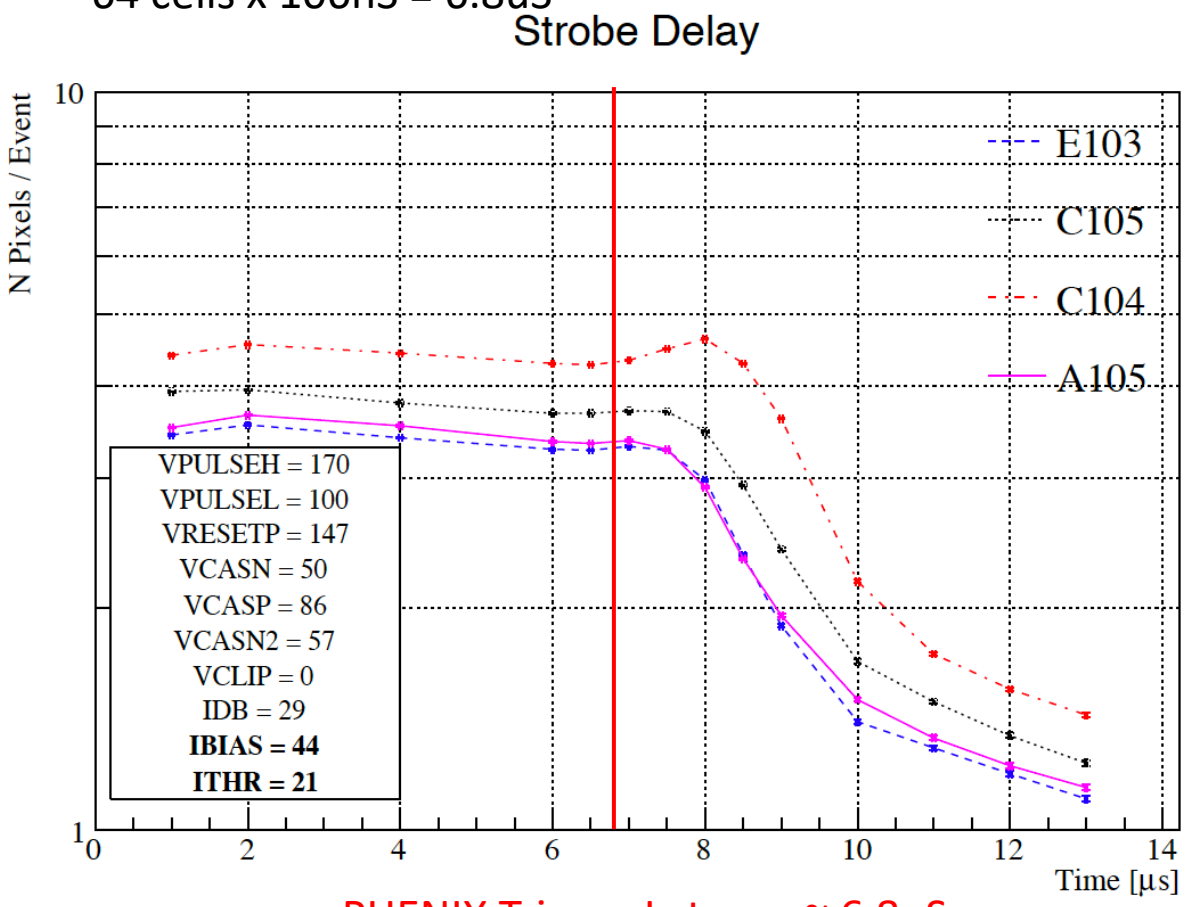
"ALICE Default Settings"
- "Pile up" integration time ~ 5uS



sPHENIX Trigger Latency ~ 4.7uS

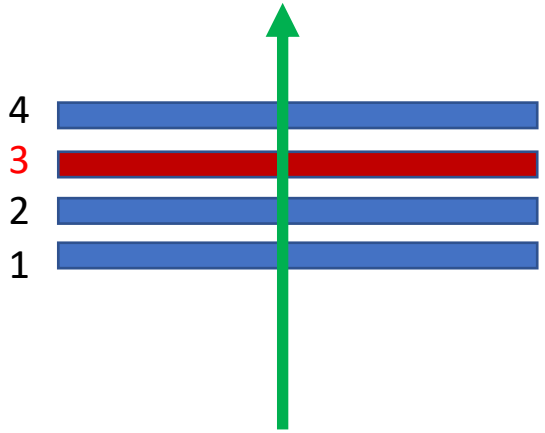
"Stretched Settings" for sPHENIX trigger study
- Pile up integration time ~ 8uS

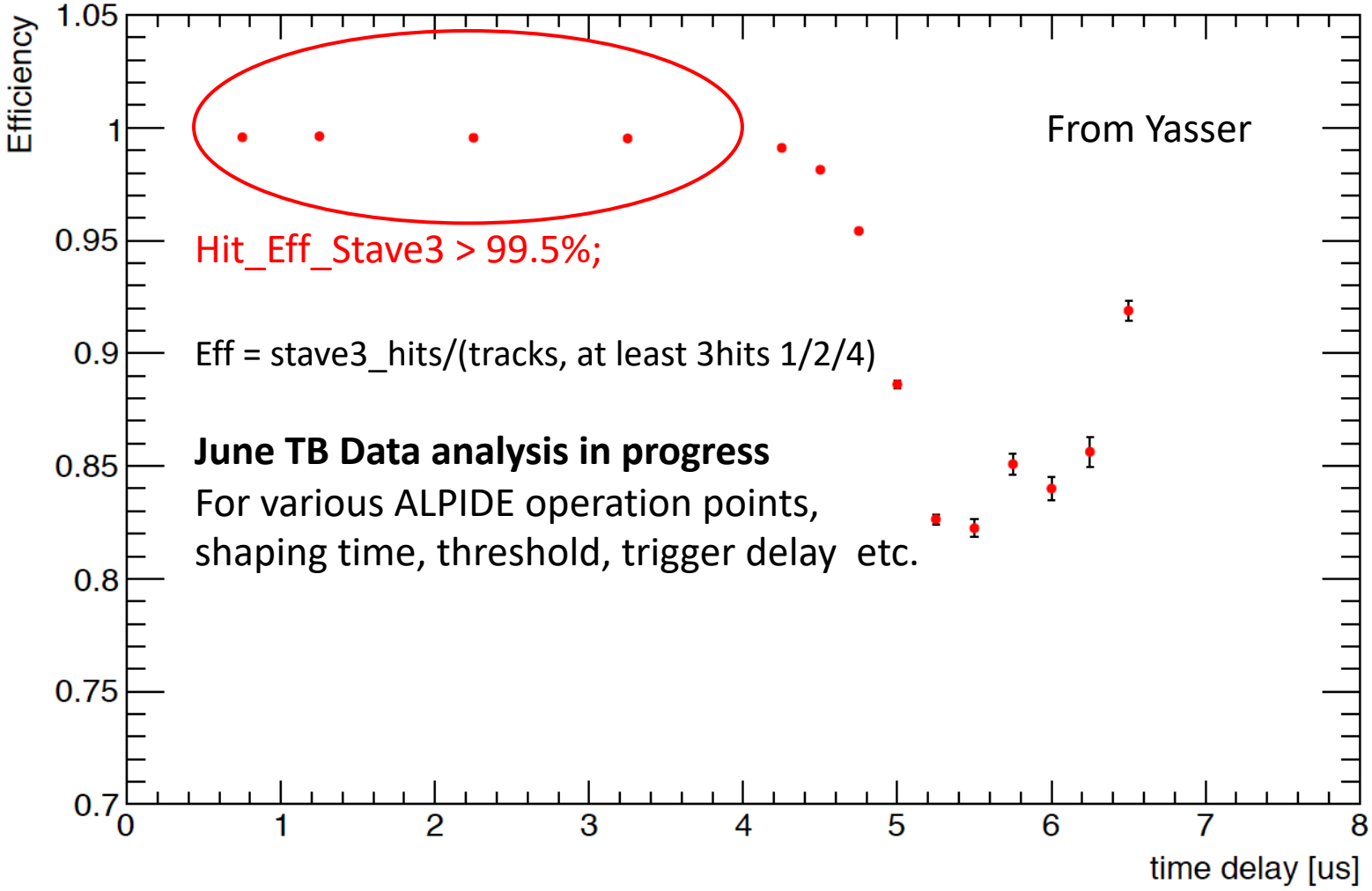
64 cells x 106nS = 6.8uS



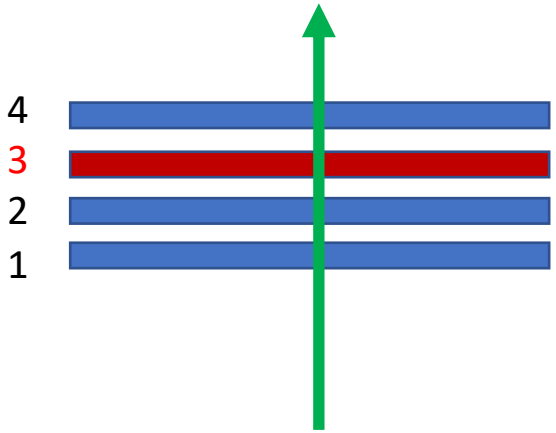
sPHENIX Trigger Latency ~ 6.8uS

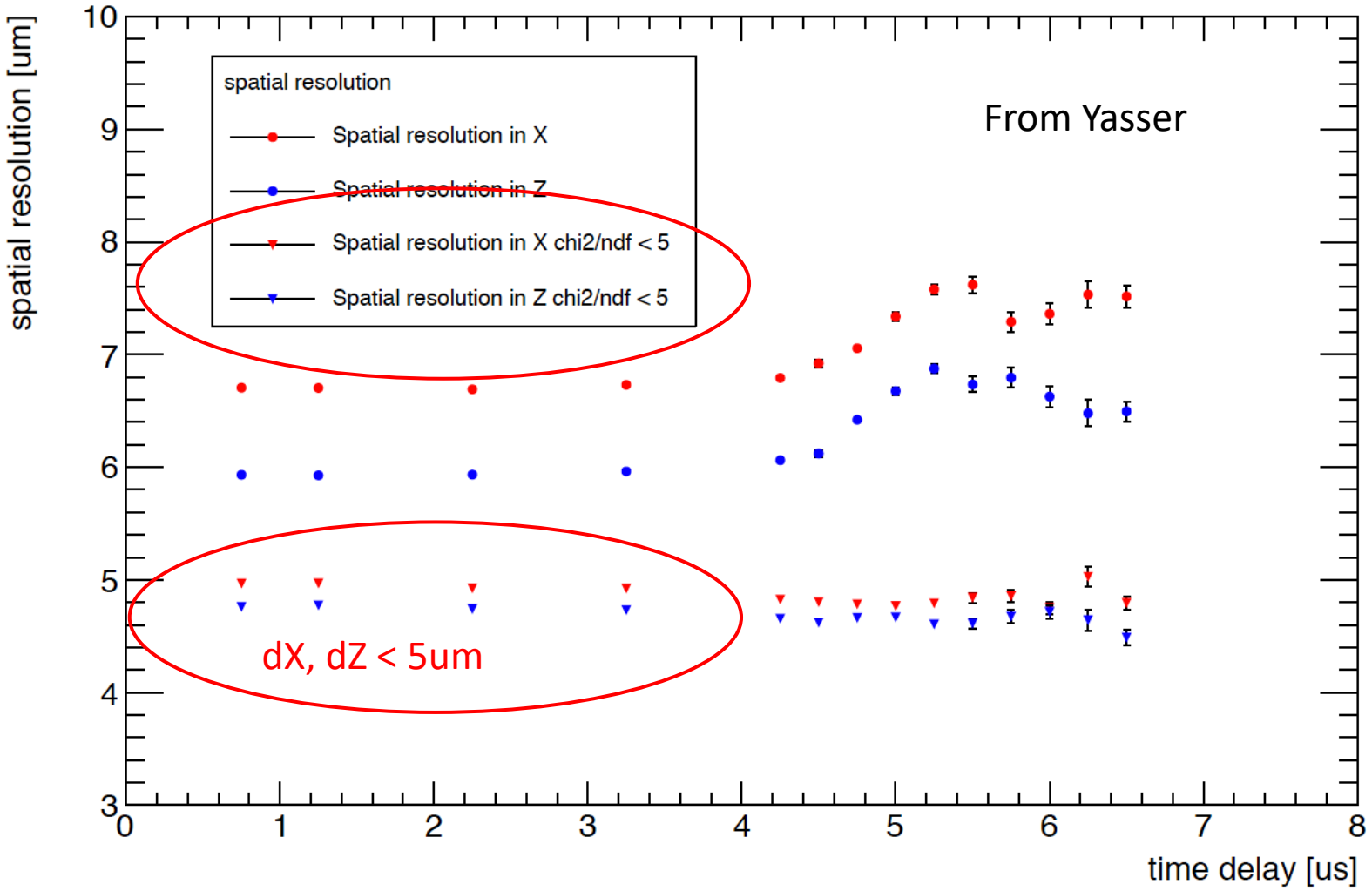
Preliminary Offline Analysis: A simple straight line fit Track hit efficiency vs Trigger Delay





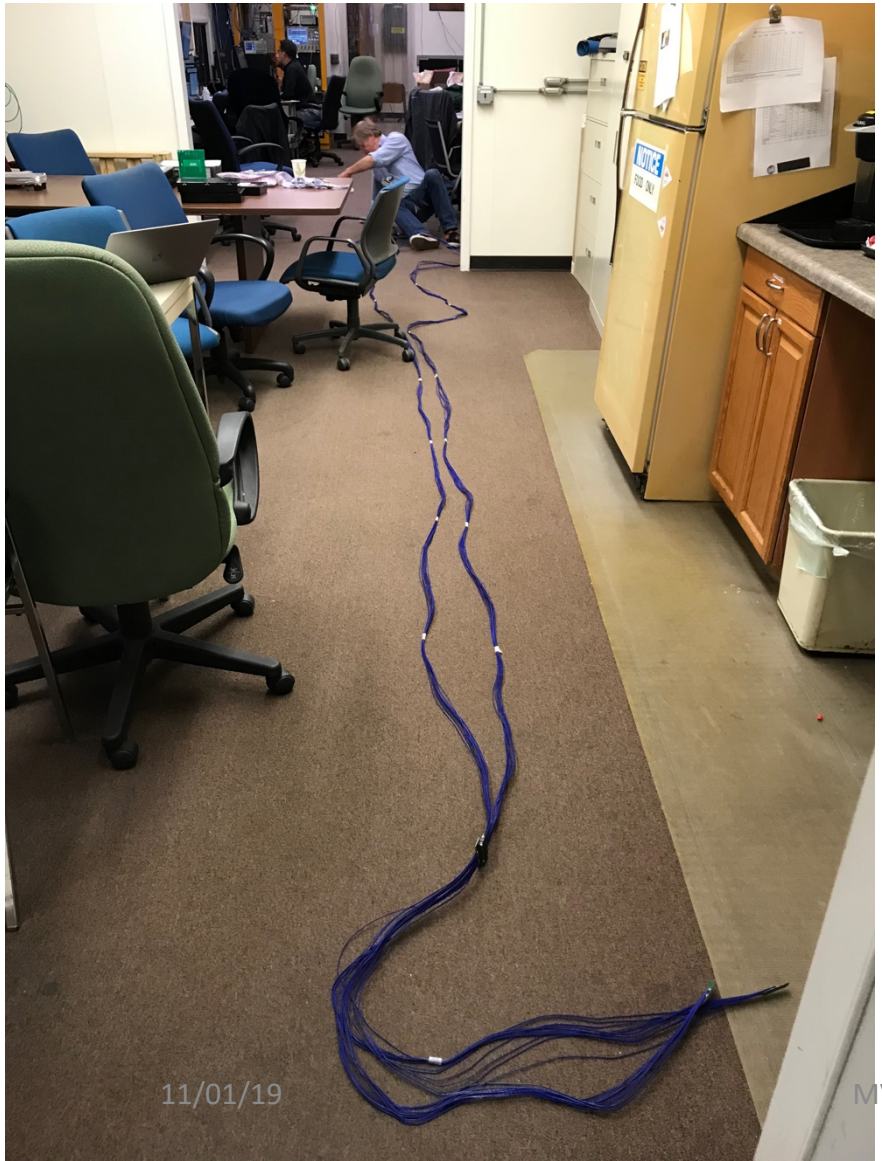
Offline Analysis: A simple straight line fit Stave-3 Track hit resolution vs Trigger Delay

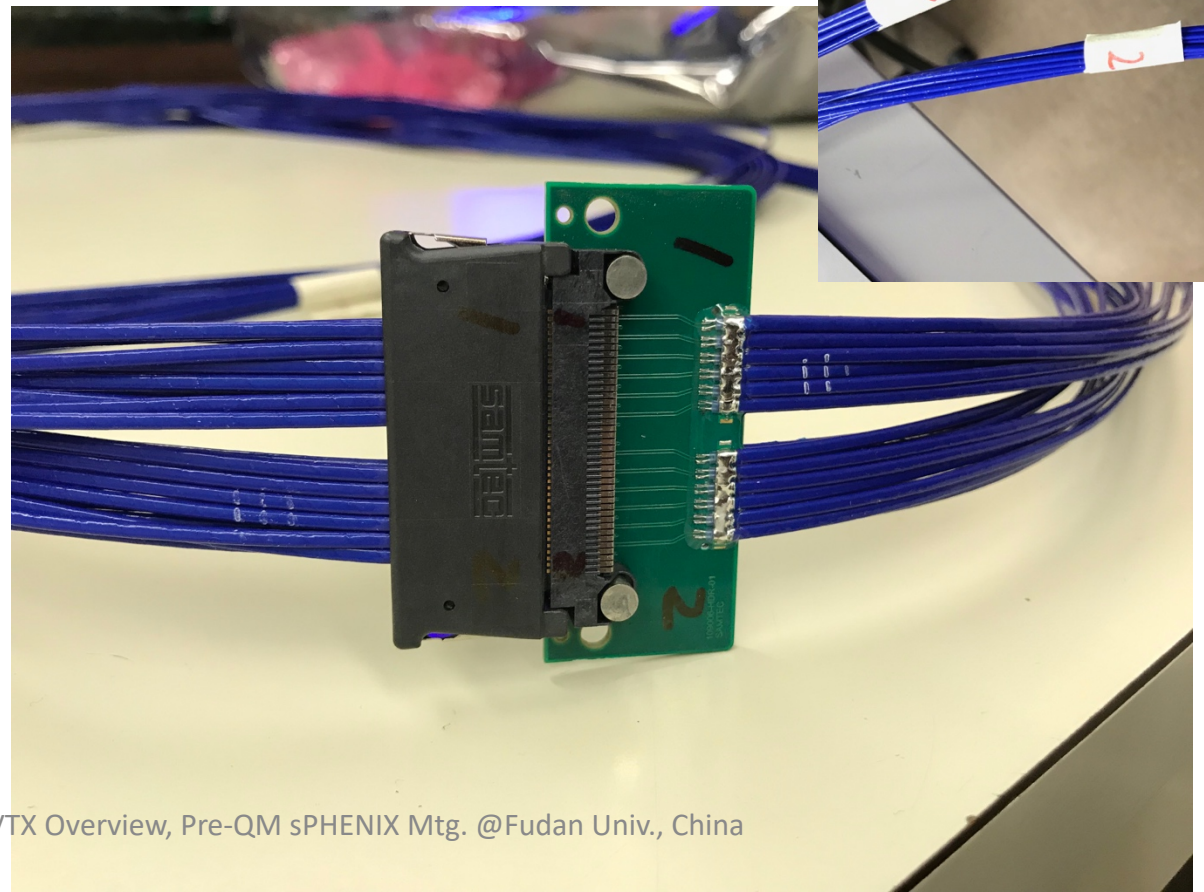


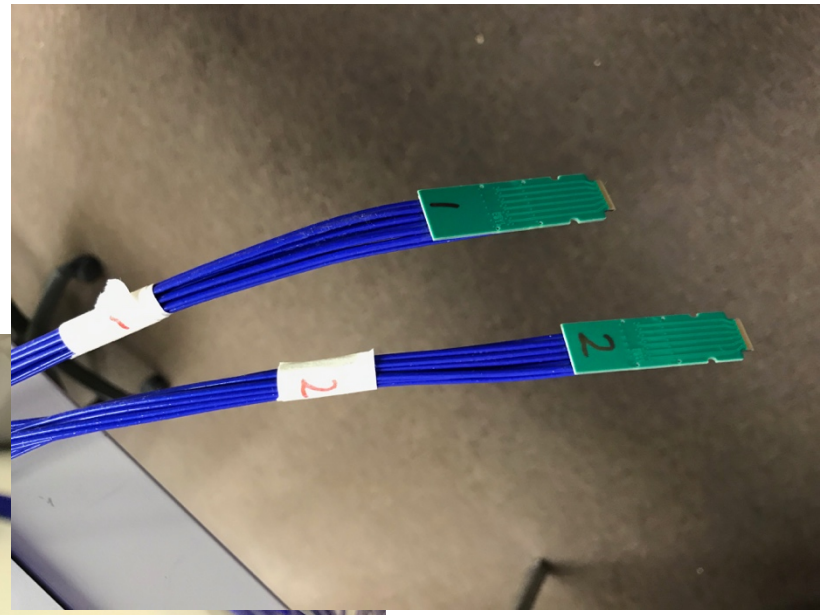


Confirmed New MVTX Long SamTec Readout Cables

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

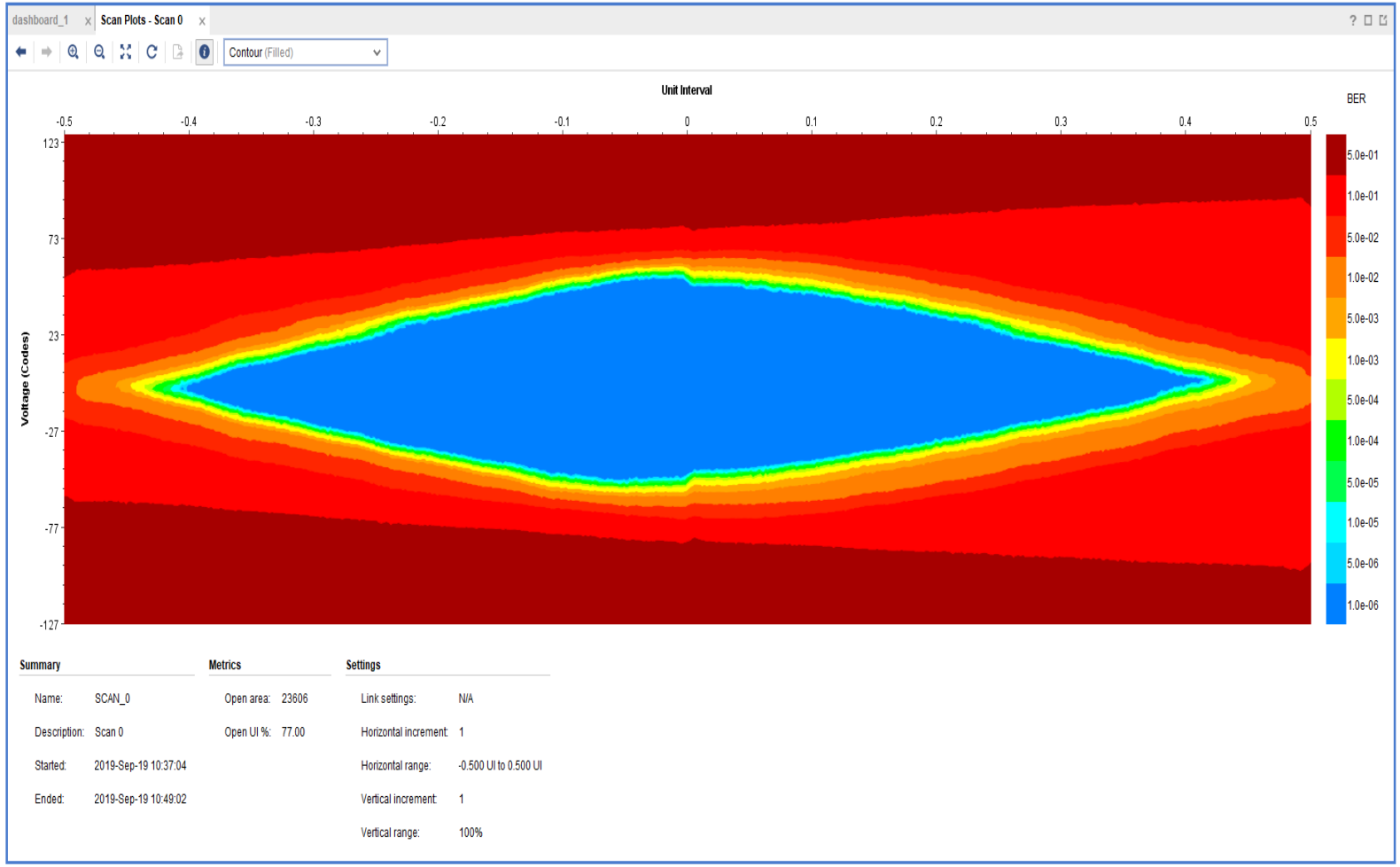


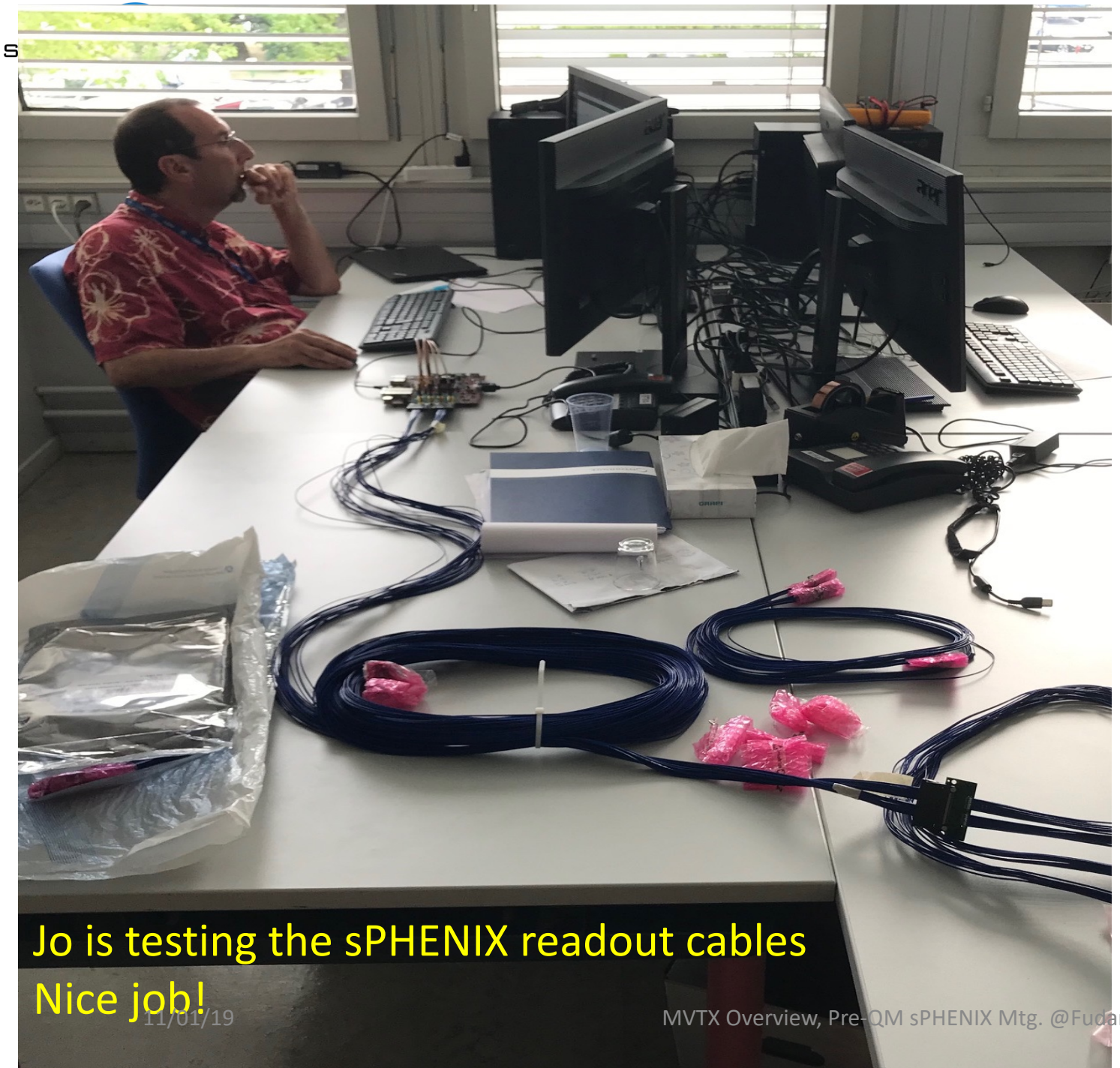




11.4m SamTec Readout Cable Tested @CERN

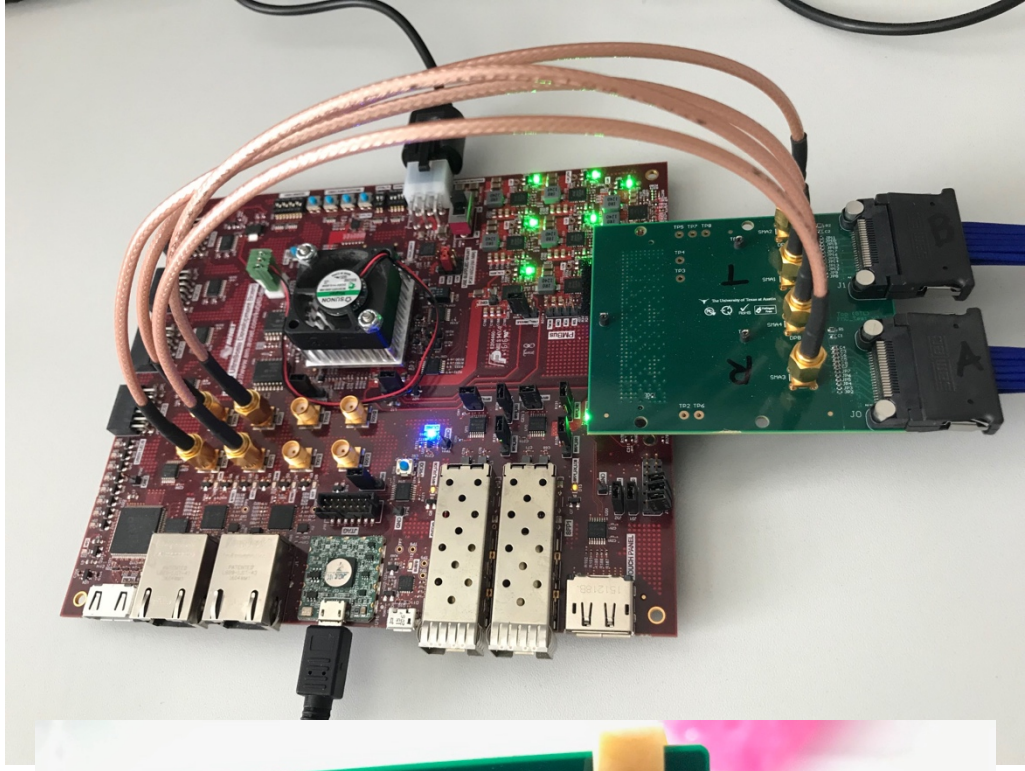
- Double looped readout cables:
  - Effective length = 2 x 11.4 m = 22.8m
  - Data rate: 1.2Gbps
  - One overnight run, ~10hrs
  - Error rate < 1.4 x10^{-14}
- **Production cable: 11m (>10m)**

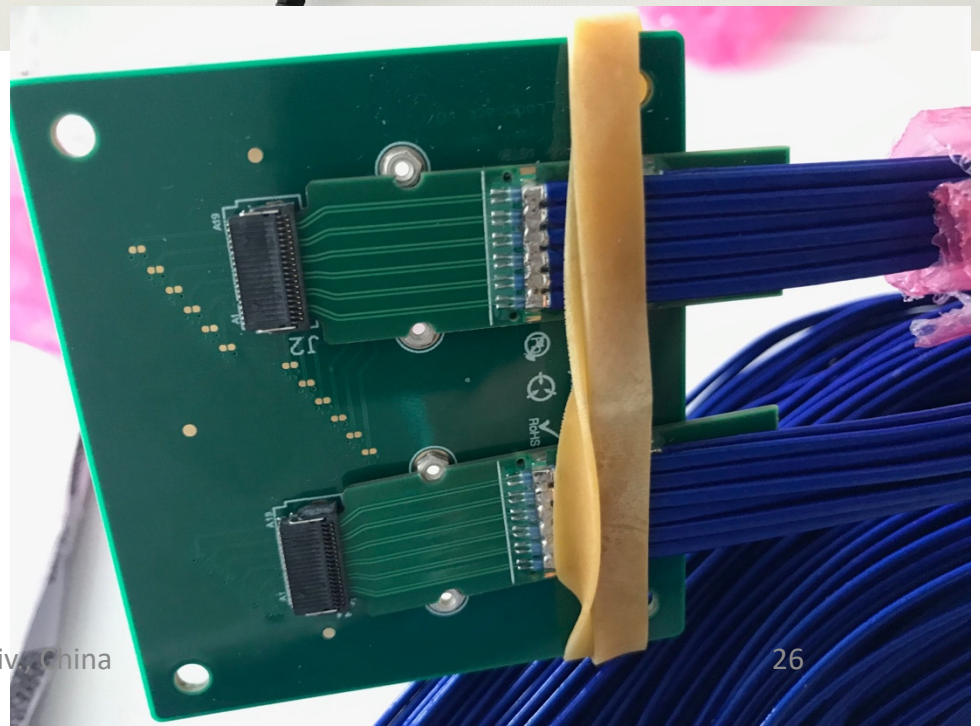




Jo is testing the sPHENIX readout cables

Nice job!



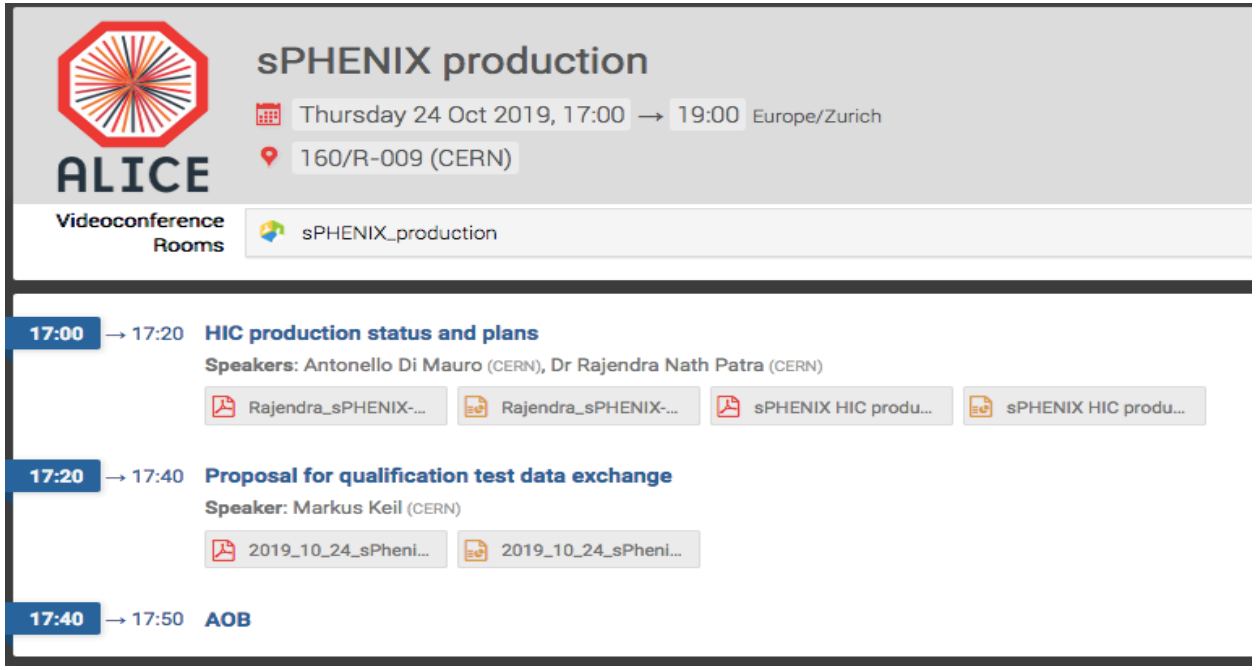


sPHENIX Stave Production Started @CERN

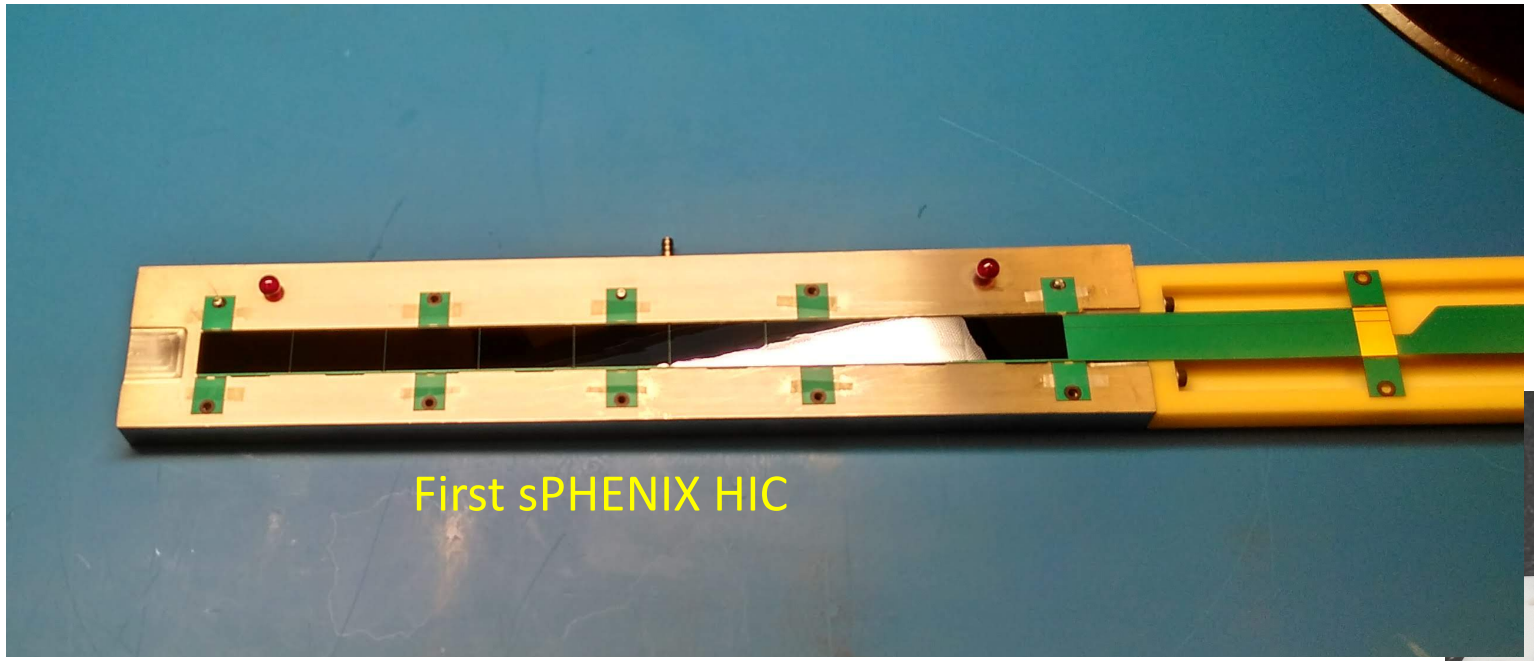
- sPHENIX Production started in 9/2019
  - Bi-weekly meeting on Thursday 5PM/CERN (9AM/LANL)
- ~10 staves/month
  - Limited by Wire bonding , 2~3 staves/week
- Production period: ~10 months
  - Complete by the end of 2020
- Produce 12 HICs in 2019
- First ~21 staves available, 3/2020

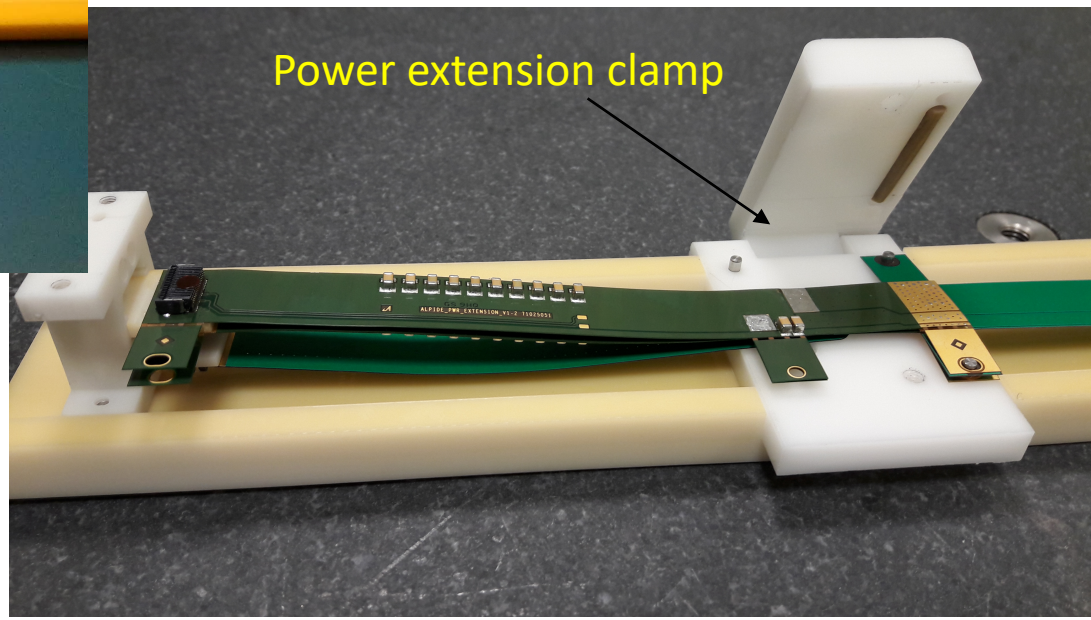
First stave production kick-off meeting 10/24

- "The FPC production is well advanced, we have already the first batch of 24 pieces available."
- ~100 golden chips available
- 1st sPHENIX HIC produced, "GOLD", IBHIC-A201



1st sPHENIX HIC Produced at CERN - IBHIC-A201 & PWR extension clamp





IBHIC-A201

Accepted ALPIDE Chips from T847786 19T: A1*, A2, A4, A5, B1, B3, B7, C2, C3

*Dust removed from the back side.

Activities	Ins. after glue	Bonding	Ins. after bonding	Power test	Qualification test	HIC+SF+CP glue	= Stave Ready?
Done?	YES	YES	YES	YES†	YES†		

† With a new set up. PWR extension connection is made using a clamp. Pictures in the next slide.

IB HIC Qualification Test on 22.10.2019:

All gold.

Eyes are okay for all the drivers settings.

Qualification flag: **Gold** (Matrix: OK (Gold)/DTU: OK)

Final Production RU Boards Tested at UT-A

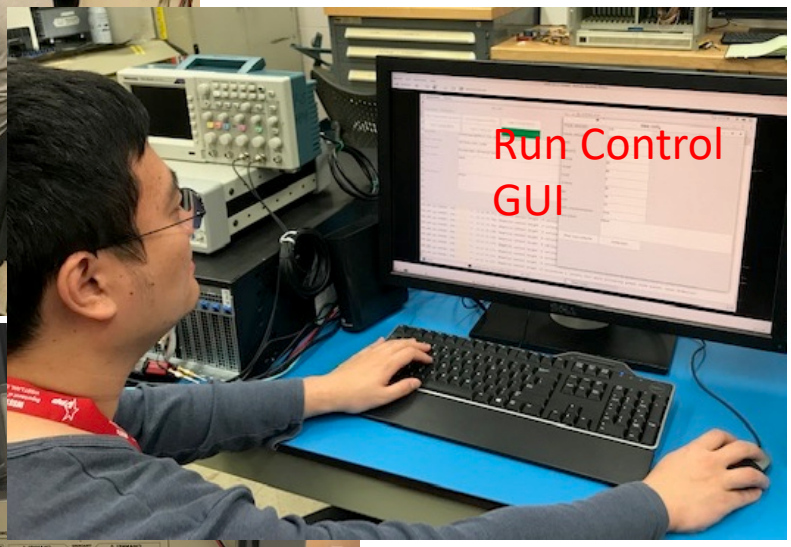
- 60 sPHENIX RUs produced at CERN
- 10 RUs produced for LANL R&D

- Tested 10 RU @UT-A, 10/14-18, 2019
  - All tested good, found one bad optical transceiver (1/30)
  - Jo, Yasser, Gerd
  - Alex T. joined for one day, readout firmware/software plan

- Plan to test the 60 sPHENIX RUs later

R&D at LANL

- Full ITS/IB QA testbench in operation
- Python GUI developed for telescope readout and control operation
- CAEN PS being tested



A Full Readout Chain System Test

- MVTX – readout in 6-subgroup
  - 48 staves + 48 RUs + 6 FELIXs

  A complete readout chain:
  8 staves + 8 RUs + 1 Felix + 1 RCDAQ Server

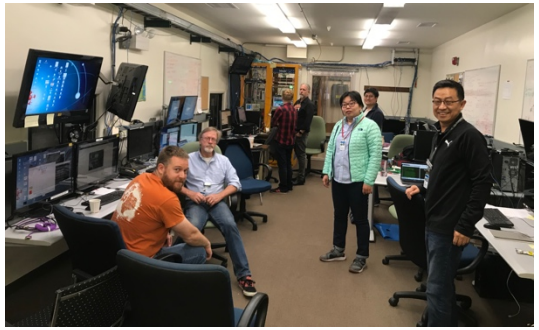
- Hardware in hand at LANL
  - 6 staves + 4 HICs(w/o carbon frame)
  - 10 RUv2.1
  - 2 FELIX v2.0
  - 2 PU
  - 1 sPHENIX GTM

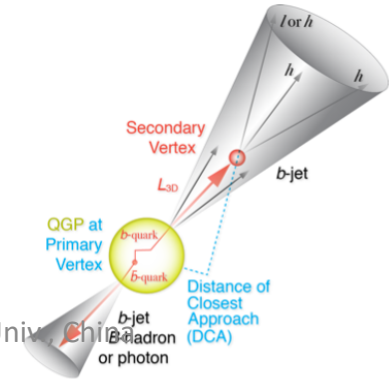
Build a telescope of:
- 6 staves + 2 HICs
- 8 RUv2.1
- 1 FELIX
- 1 PU
- 1 GTM

A test beam later this year or 2020 (TBD)
- LBNL, 50MeV p-beam
- LANL, 800MeV p-beam
- Fermilab?

Summary

- Completed key 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
  - Vendor selection
  - Carbon structure (pre)production
  - Insertion mockup
- 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
  - Acceptance test & QA in US
- July MVTX review response submitted to DOE
  - Expect project $$ distributed soon





We are ready for the full production and the physics!

backup

Near Term To-Do List

- Continue mechanical system design
  - CYSS, EW, SB
  - Global insertion system design and full mockup
- Carbon structure production
  - LBNL CF update
  - Follow up with US vendors for quotes
  - Select vendor(s) for pre-production
- RU acceptance QA at UTA
- Prepare for stave acceptance QA at LBNL
- FELIX production and test
  - Jointly with sPHENIX TPC, at BNL? Or LANL?
- 2019 test beam data analysis

sPHENIX Stave production at CERN

We will follow up the progress closely, production, Test & QA
- bi-weekly meetings with CERN

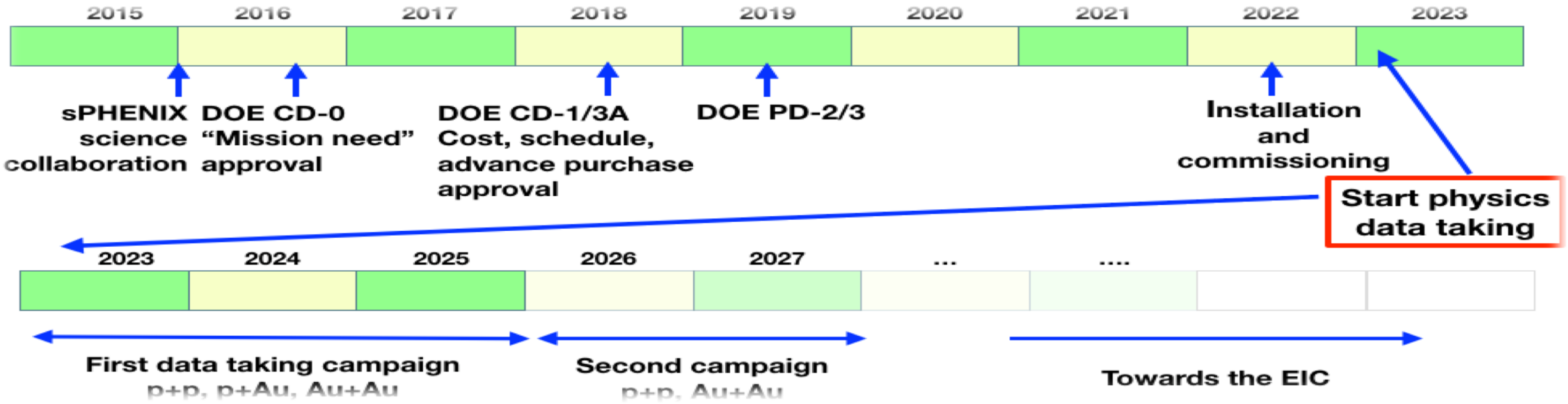
ITS system surface commissioning at CERN

Now --- May 2020
A good opportunity to learn about the
system operation and controls;
Working on a coordinated effort within MVTX/sPHENIX,

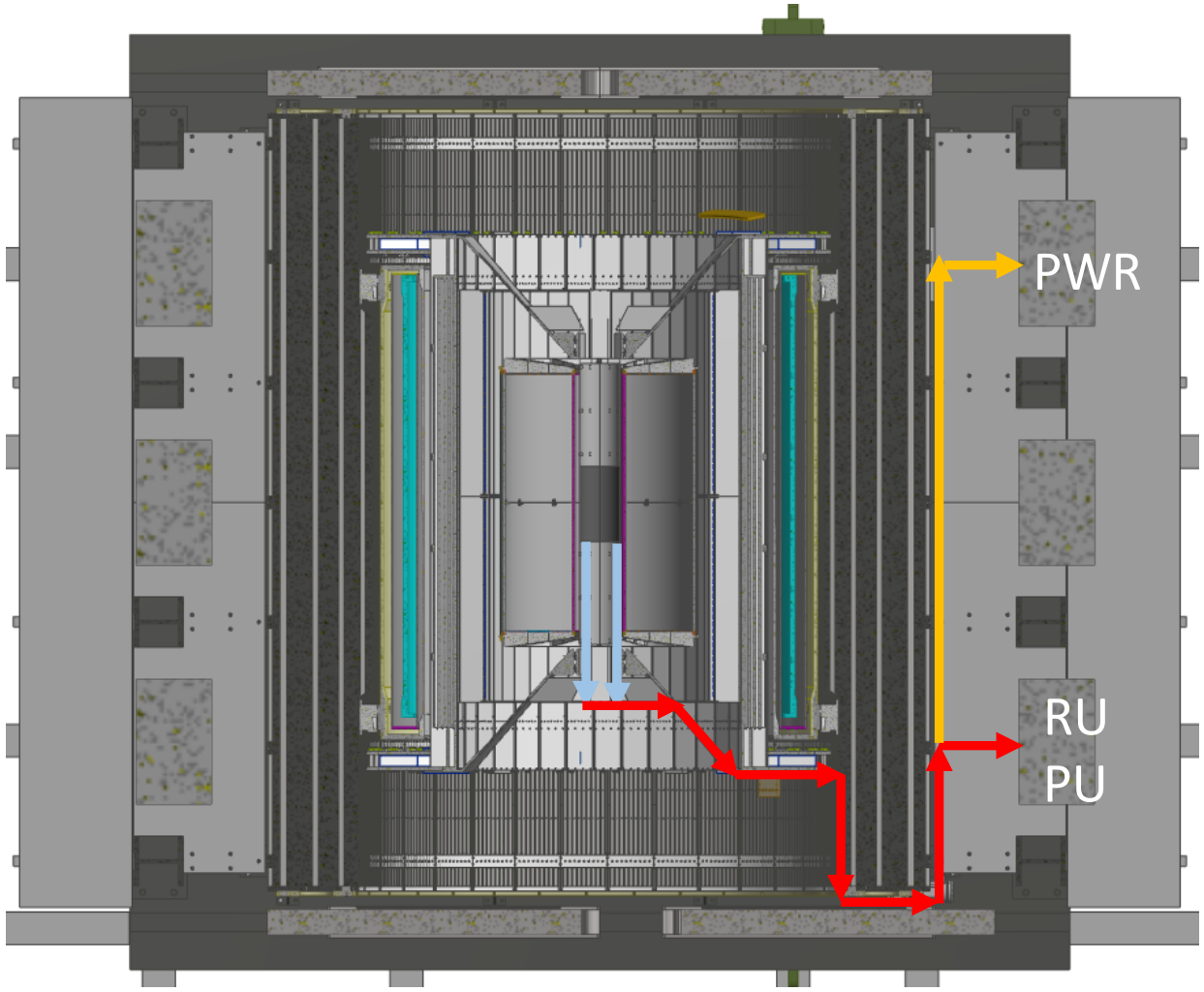
Signup page,
https://docs.google.com/spreadsheets/d/1YBAyouW8geJHUPpzRyLlzN4ePW4YzI8gll5xI66N3ww/edit#gid=0

A full “8-stave + 8-RU + 1-FELIX + 1-PU + 1 GTM” chain test
- 10 RU available
- 1 PU arrived at LANL from LBNL
- 8-stave/HICs telescope frame being designed
- RU & FELIX Firmware update in progress
- Slow control software & GUI
- A possible test beam run later this year

sPHENIX Timeline



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

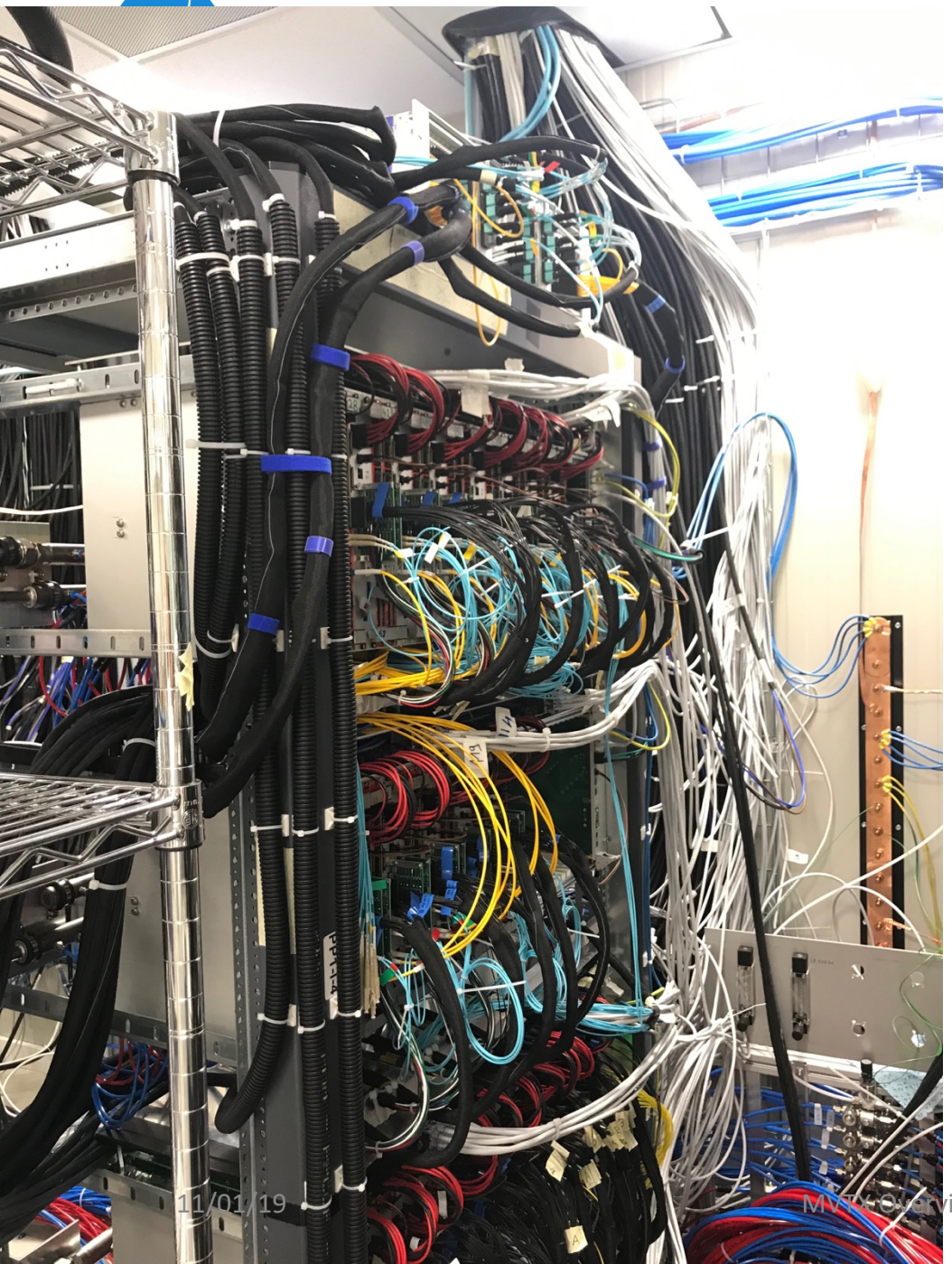
Power cable:4.7+ m

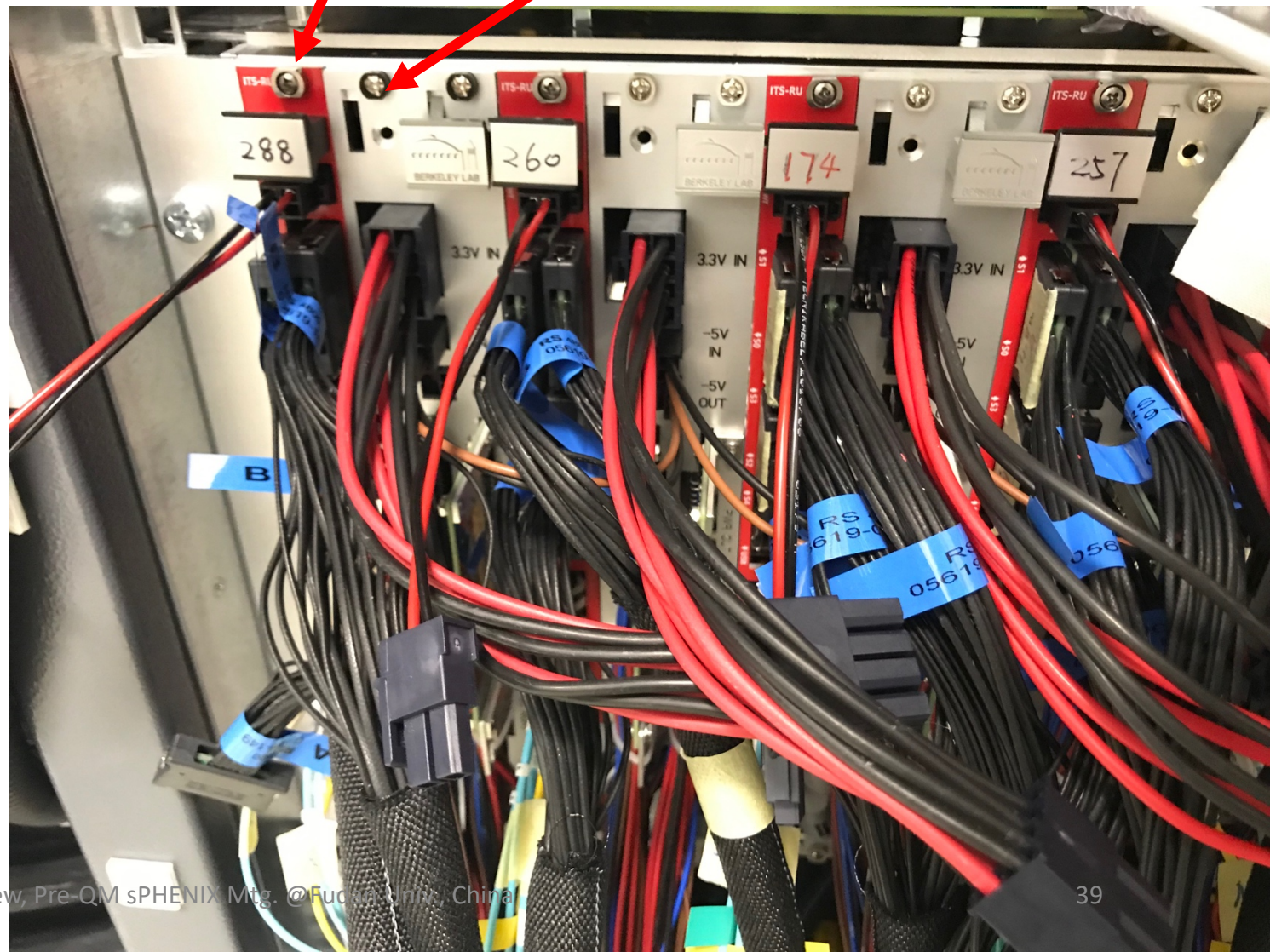
Desired ~10m

Carbon Structure Production

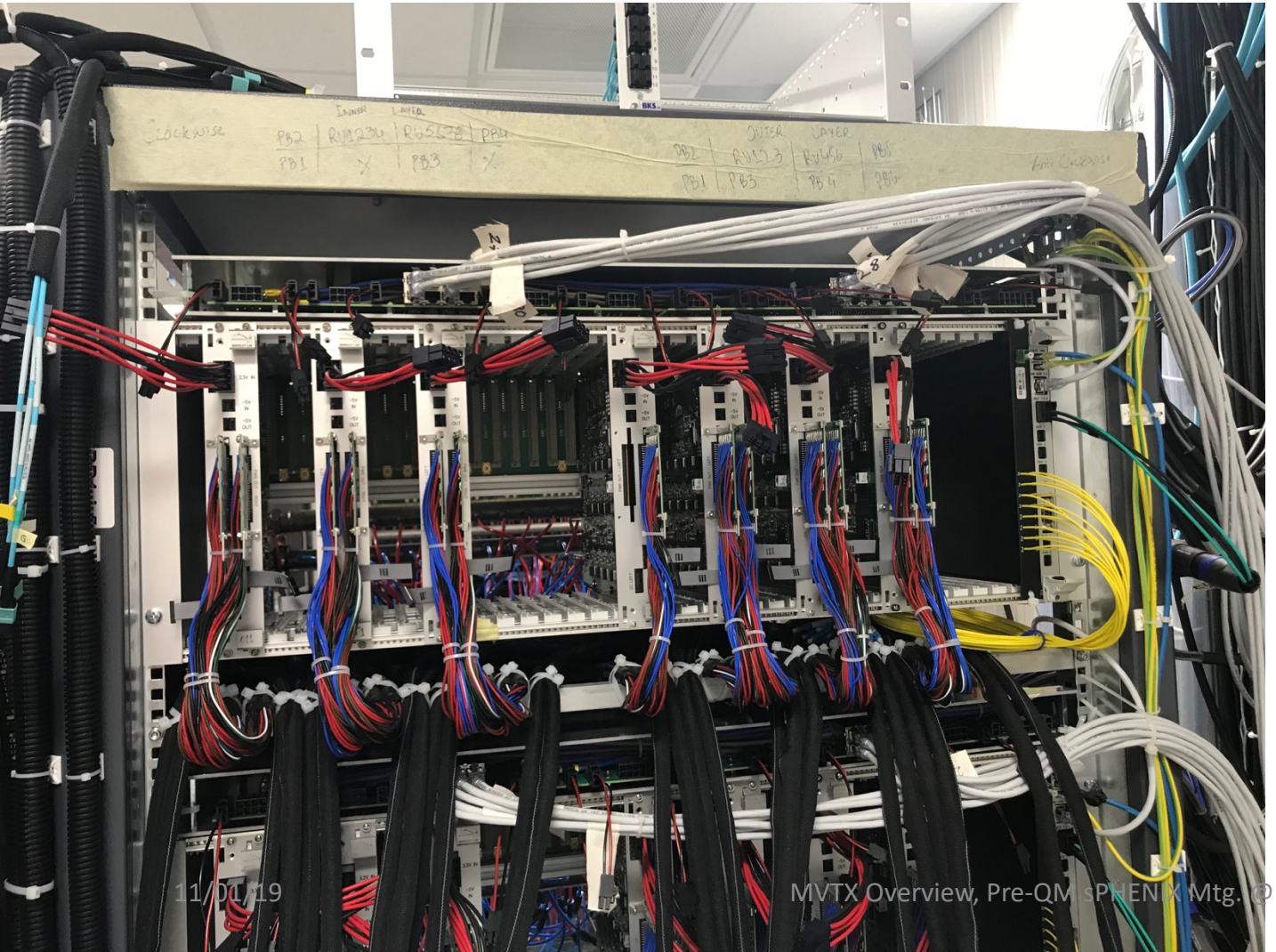
- Visited WorkShape 9/19/2019
  - Walt and Ming, Simon
- WorkShape well prepared
  - Updated the design files
- MIT design work good progress, well ahead of time
  - Early Carbon structure review for pre-production, Nov/Dec 2019?
- Other companies, CA..
  - Received quotes for CYSS, End-Wheels
- LBNL in progress

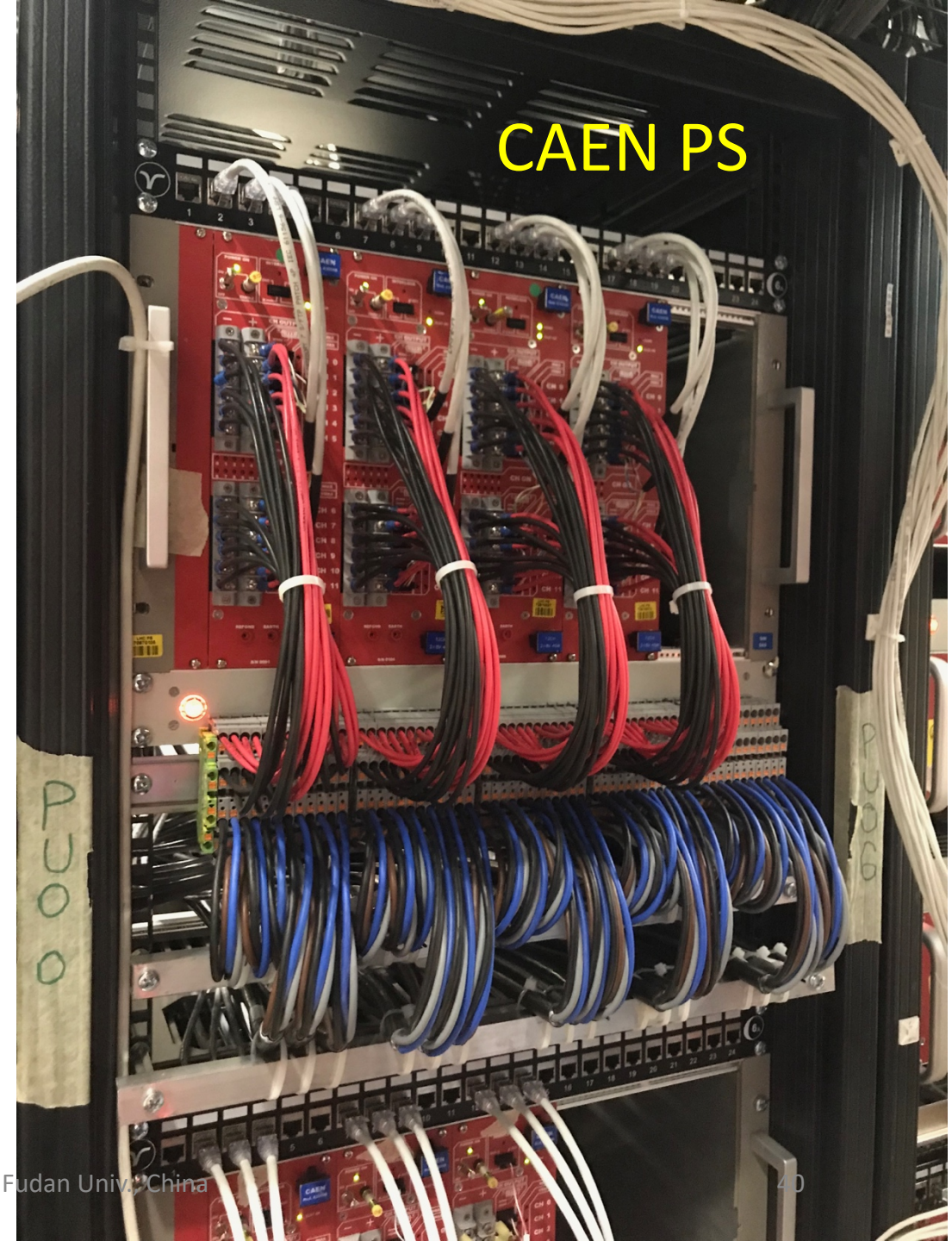
ITS/IB RU and PU, w/ cables





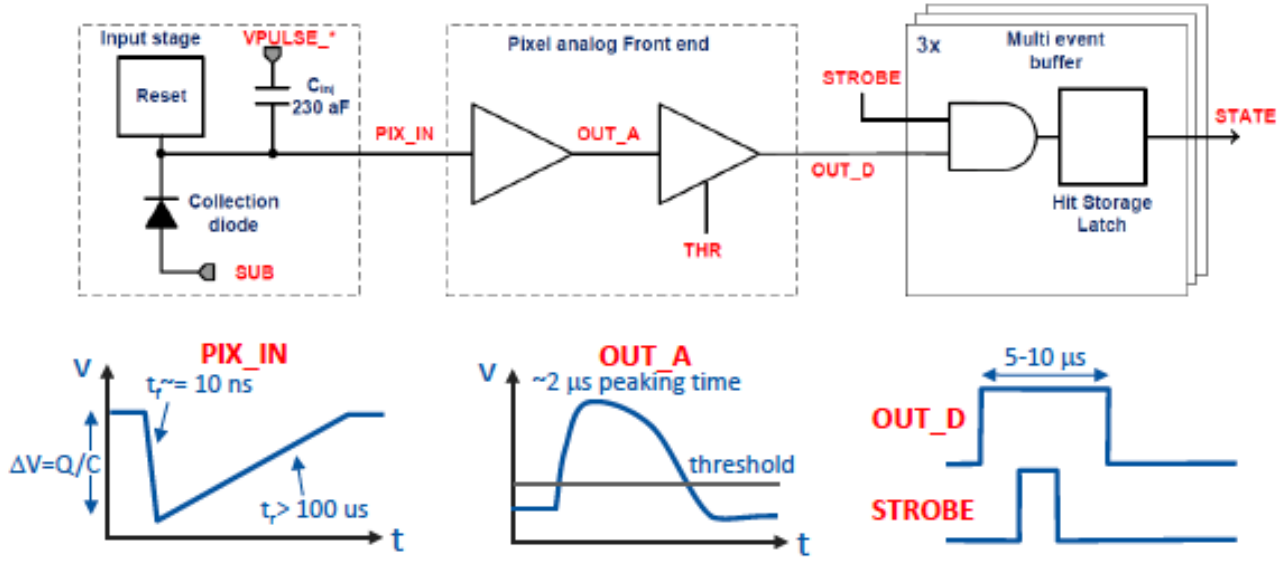
PU & CAEN PS





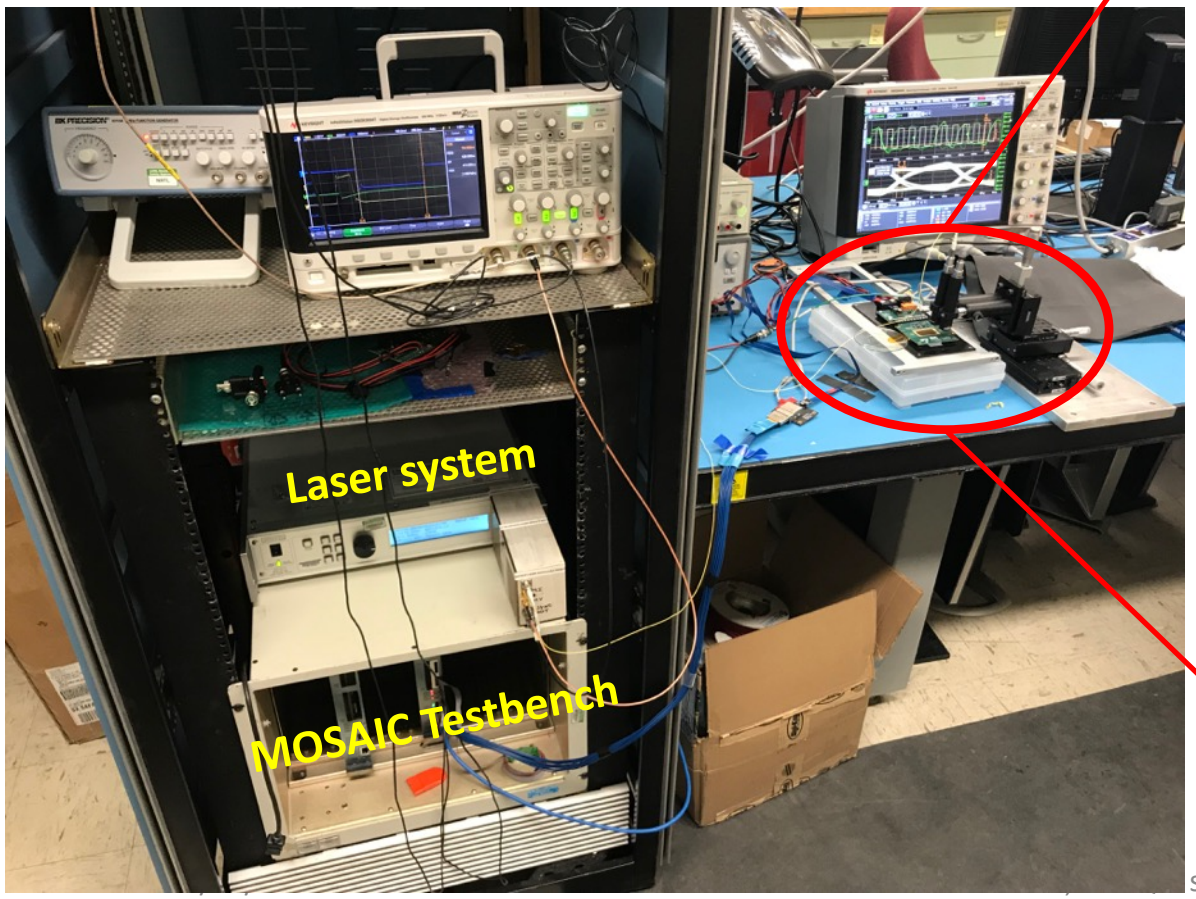
MVTX Goals – the 2nd TB, 6/17-22, 2019

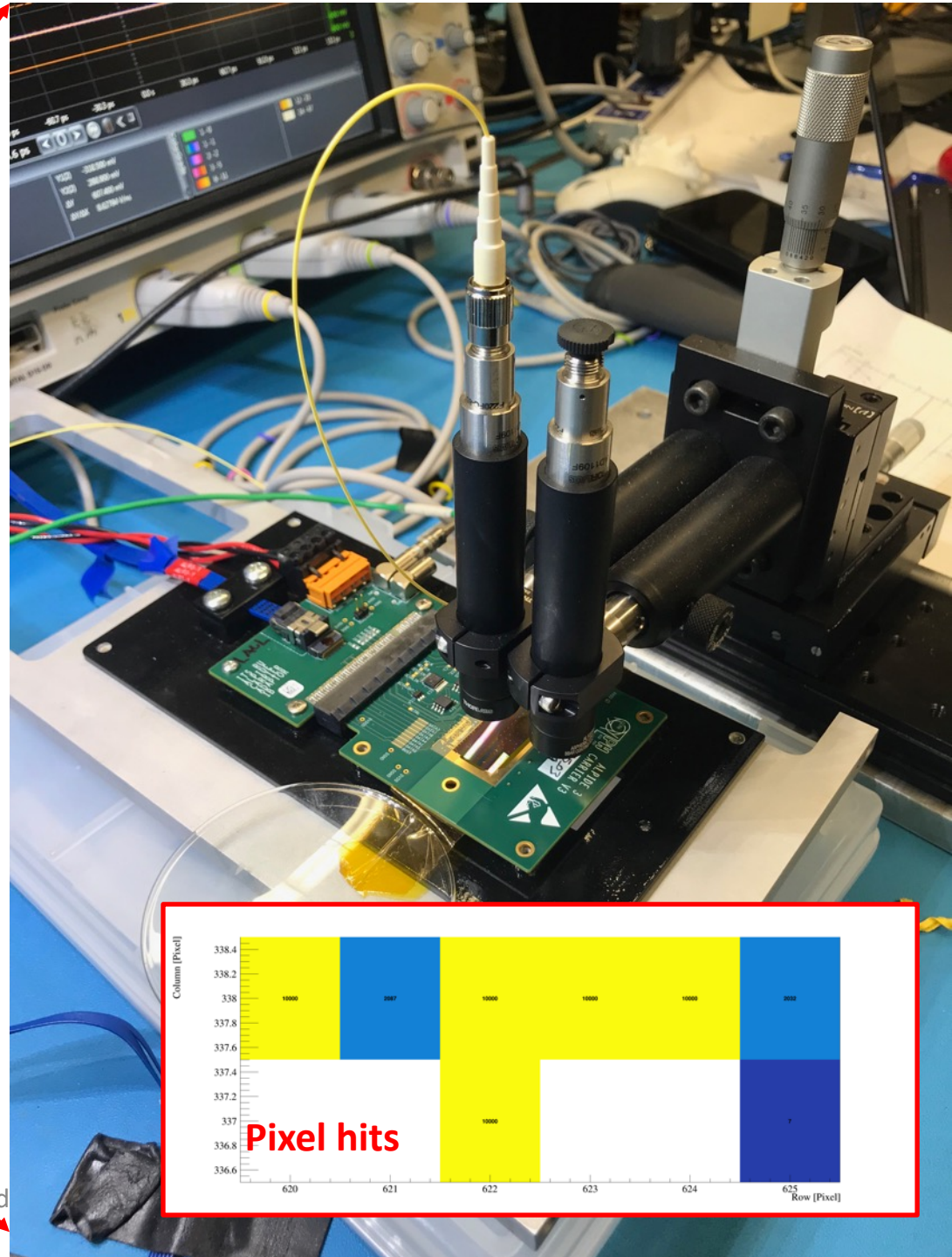
- Test and confirm optimal MVTX operation parameters for sPHENIX
  - Threshold scan, analogy shaping time etc.
  - Study chip hit efficiency vs trigger(strobe) latency
    - dT = 1 ~ 10 uS
    - Impact on occupancy & pileup
- Parameters predetermined from laser scan at LANL, in good progress
  - Single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



Study MAPS Performance with Pulsed Laser @LANL

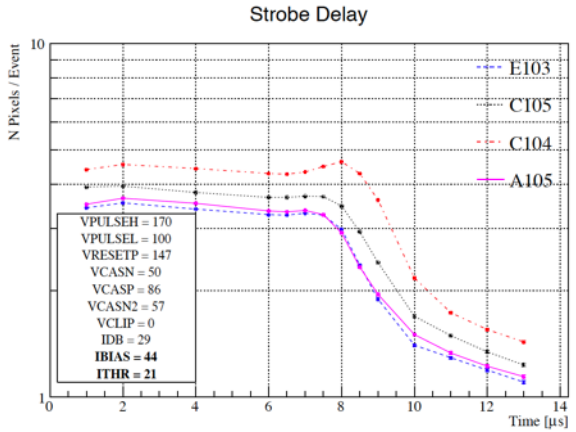
- Inject "MIP" signal, focused laser beam
  - 850 nm laser, 4ns wide pulse, ~1 MIP
  - 50kHz trigger
  - **Find optimal MAPS operating parameters**

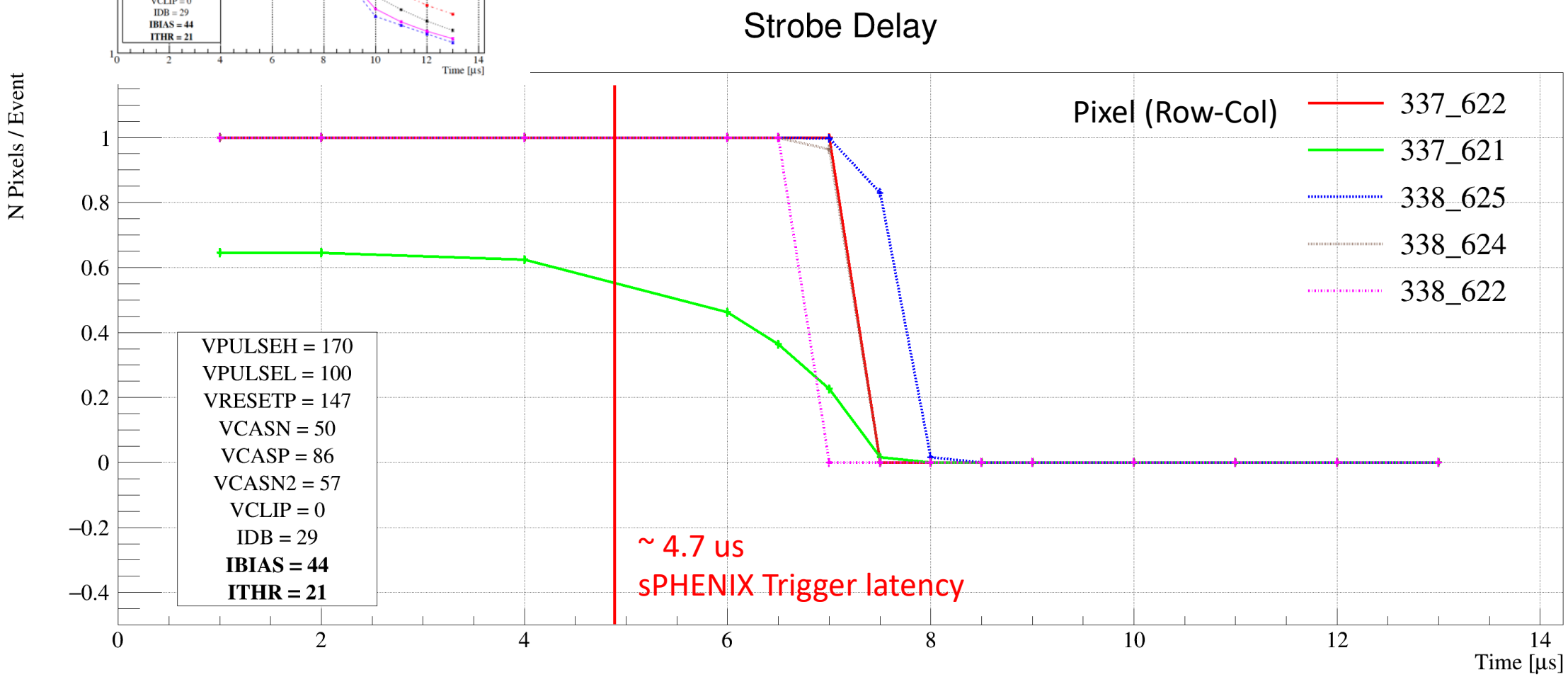




Laser Scan Data – Pixel Hit Efficiency vs Trigger Delay

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





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

Most Visited | Getting Started | MAPS-based Vertex... | MVTX Technical De... | sphenix-mvtx · GitLab

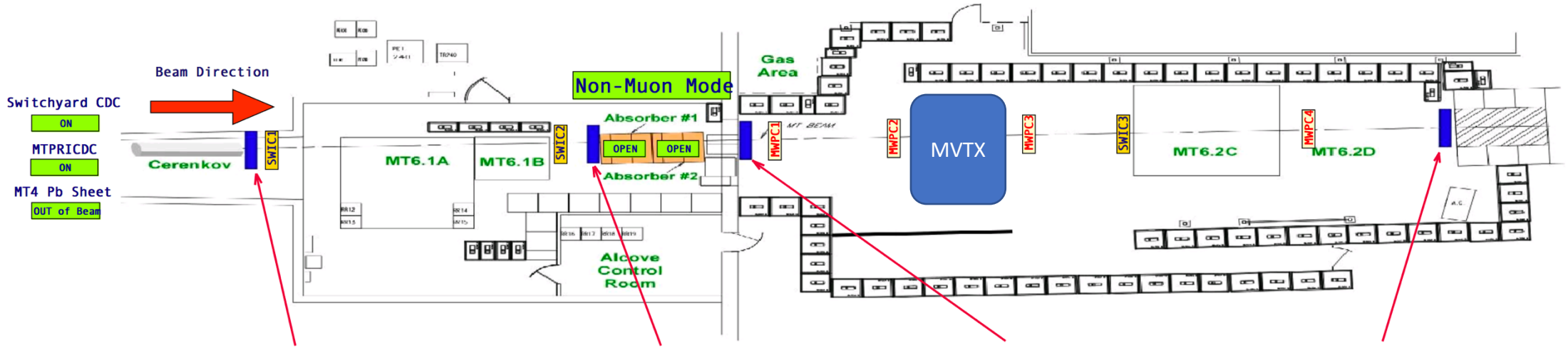
09:04:12

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

4-stave Telescope

120GeV p-beam

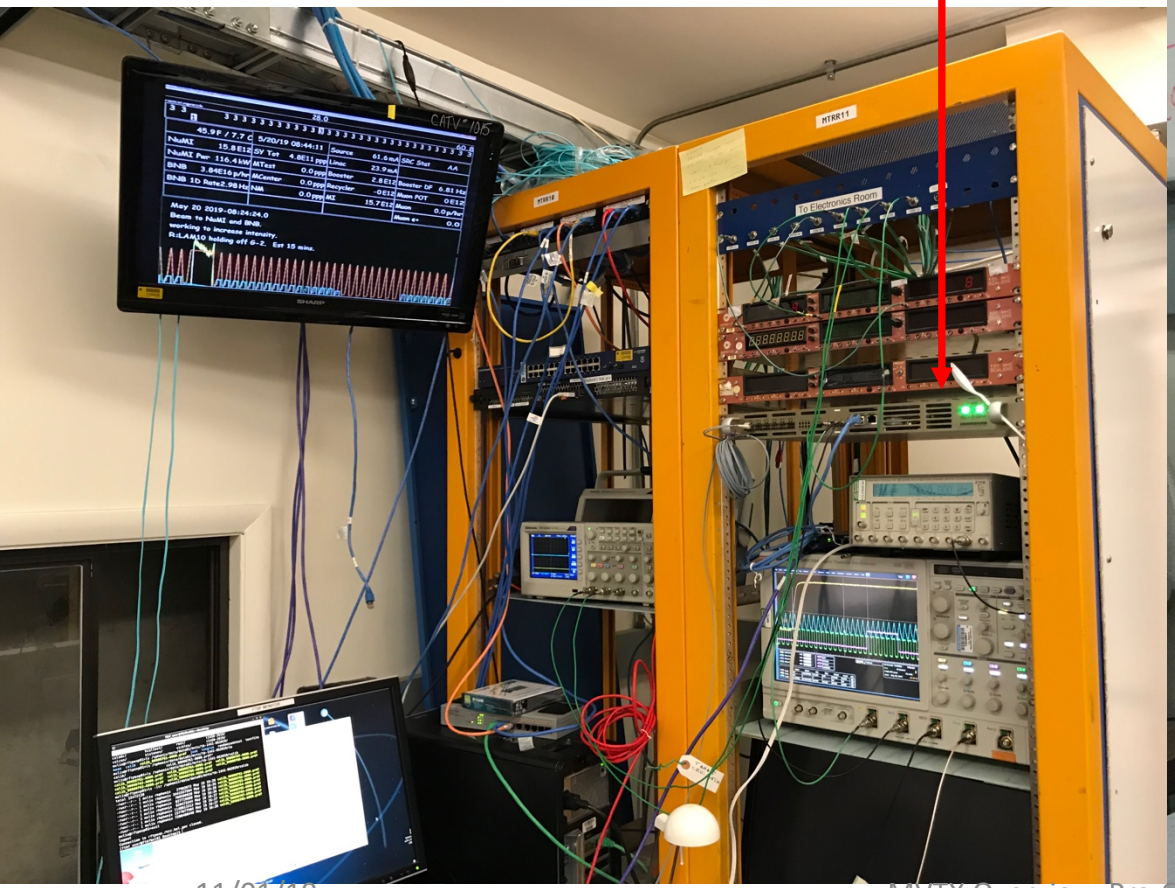
2 RUs, PU, PS

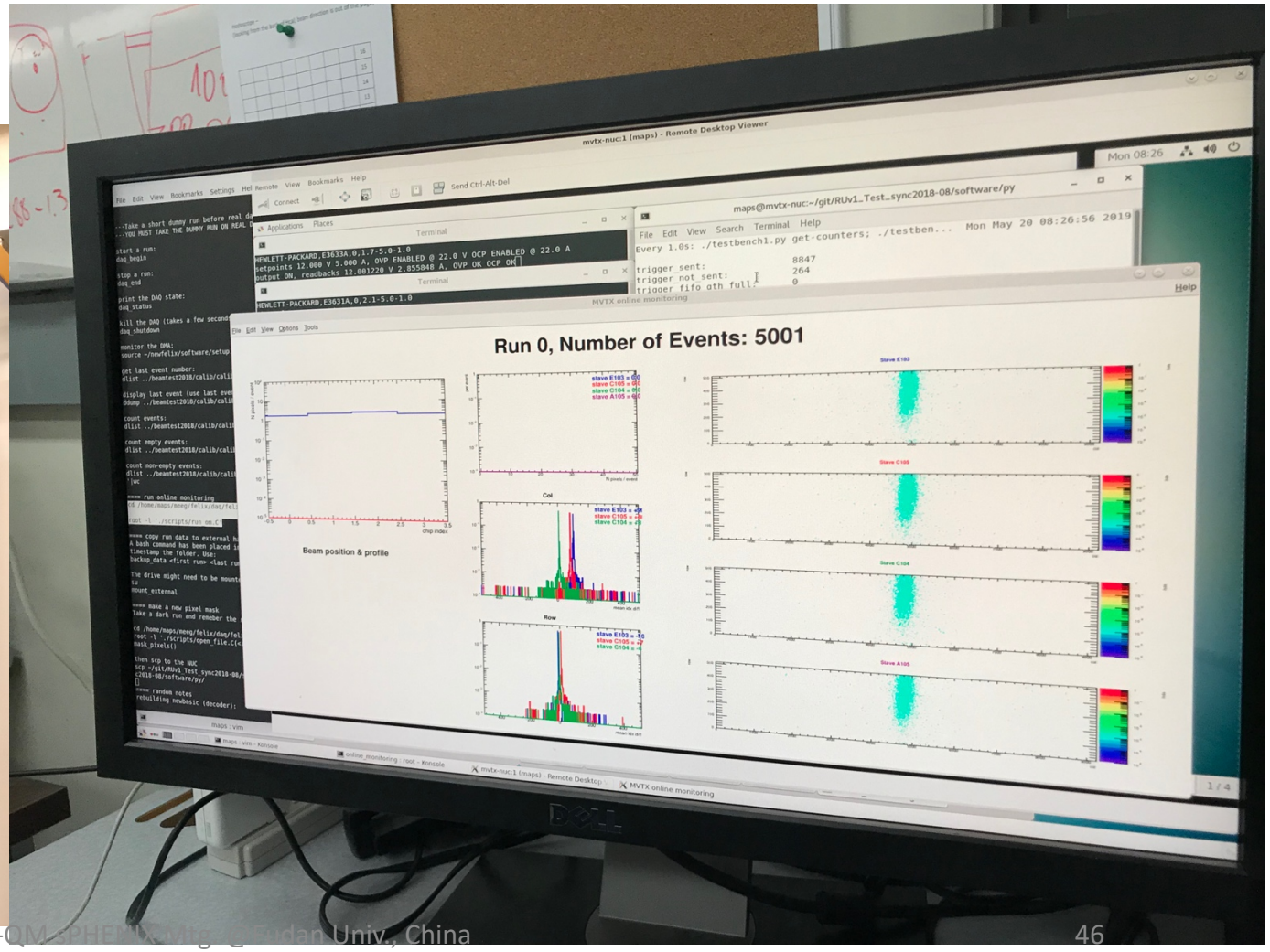
Motion Table (X,Y,Phi)

Negative Pressure Cooling System

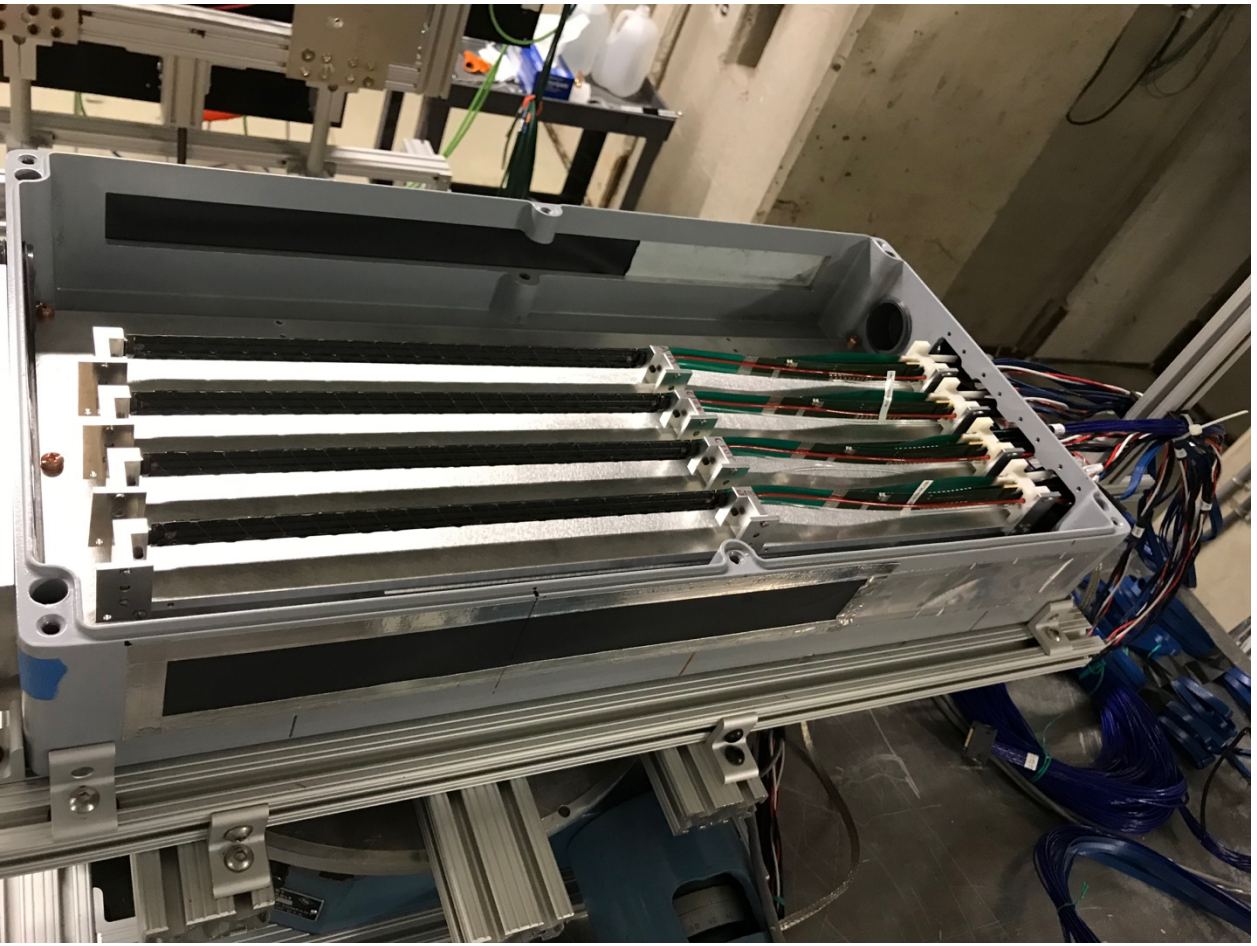
First Collision Signals

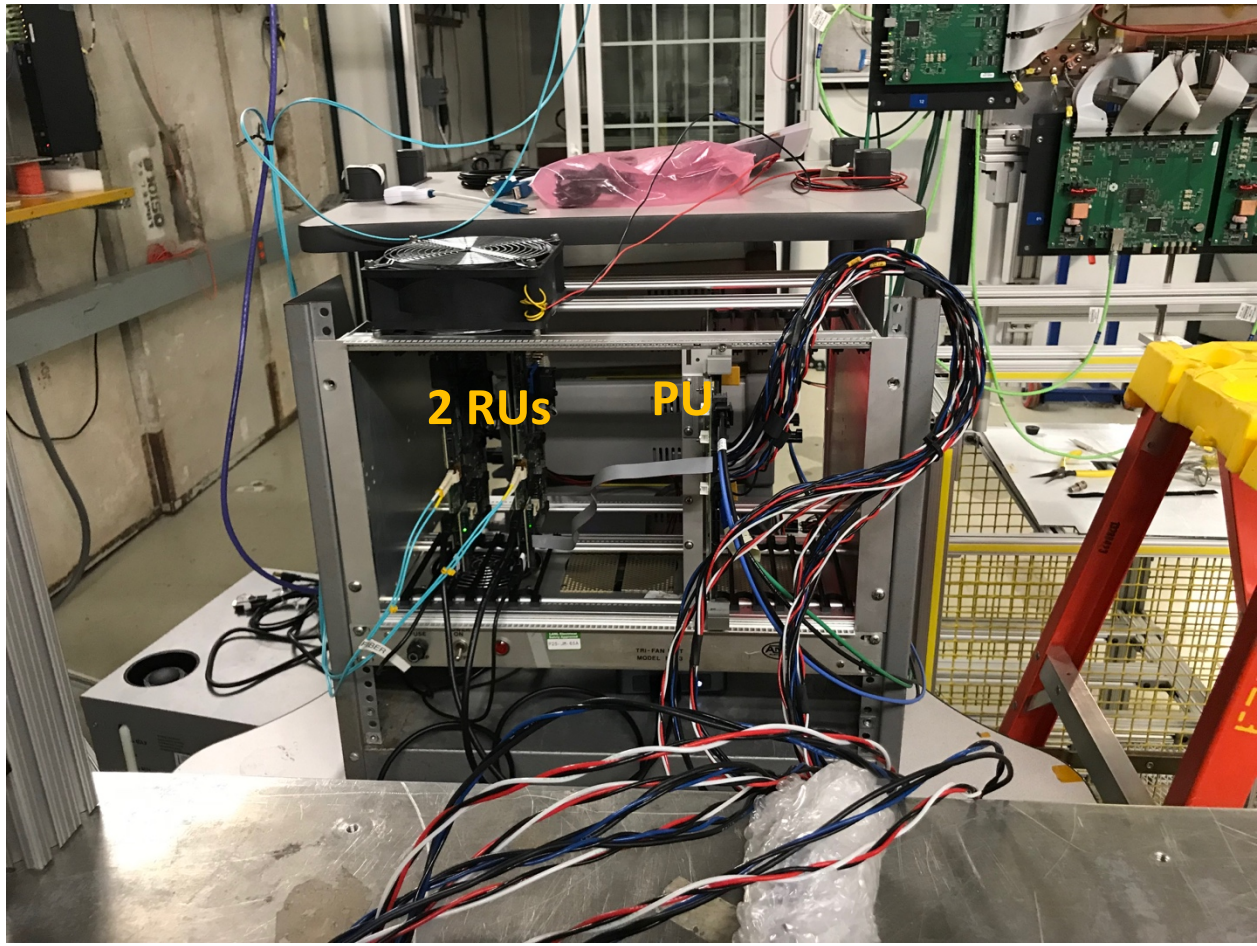
sPHENIX GTM

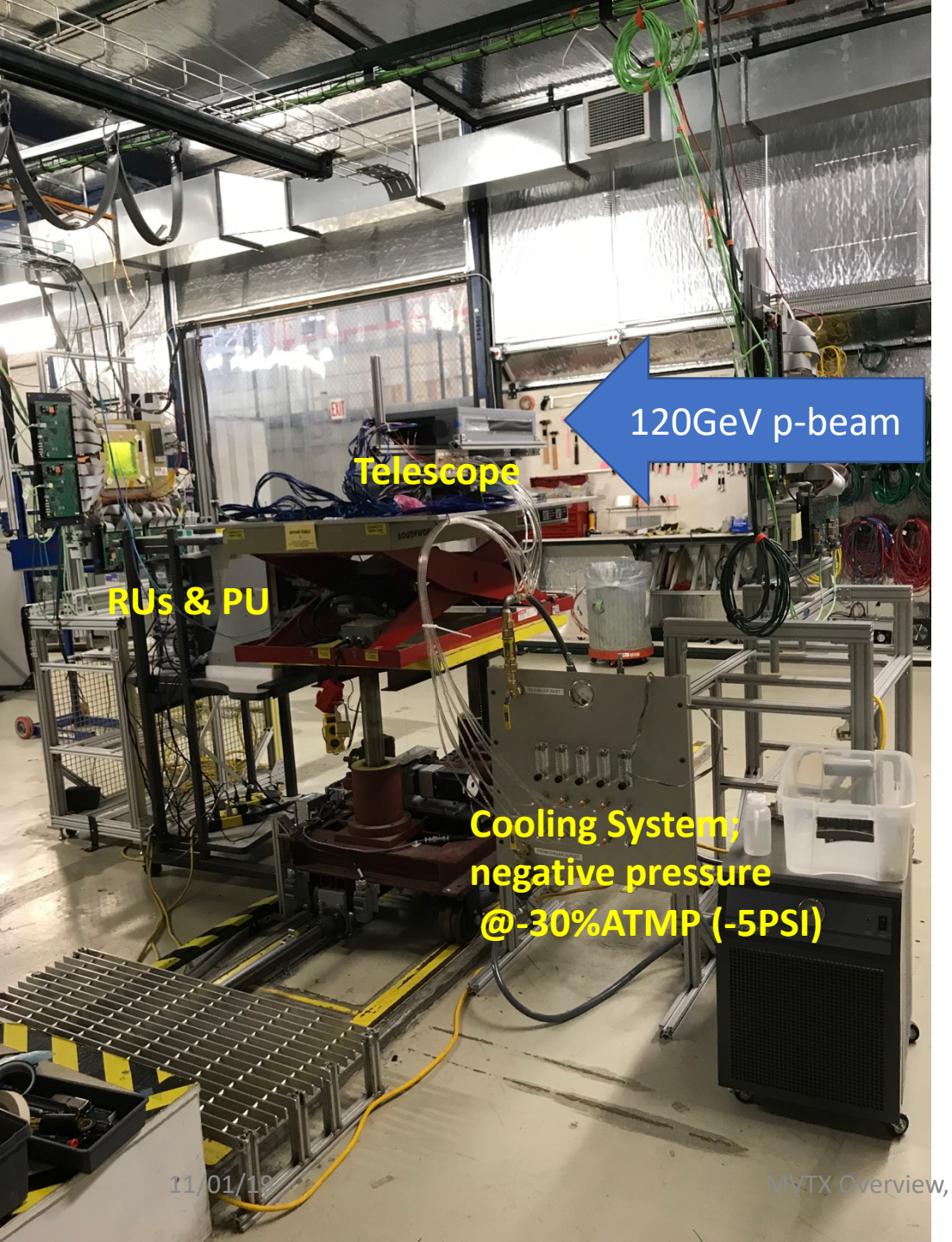


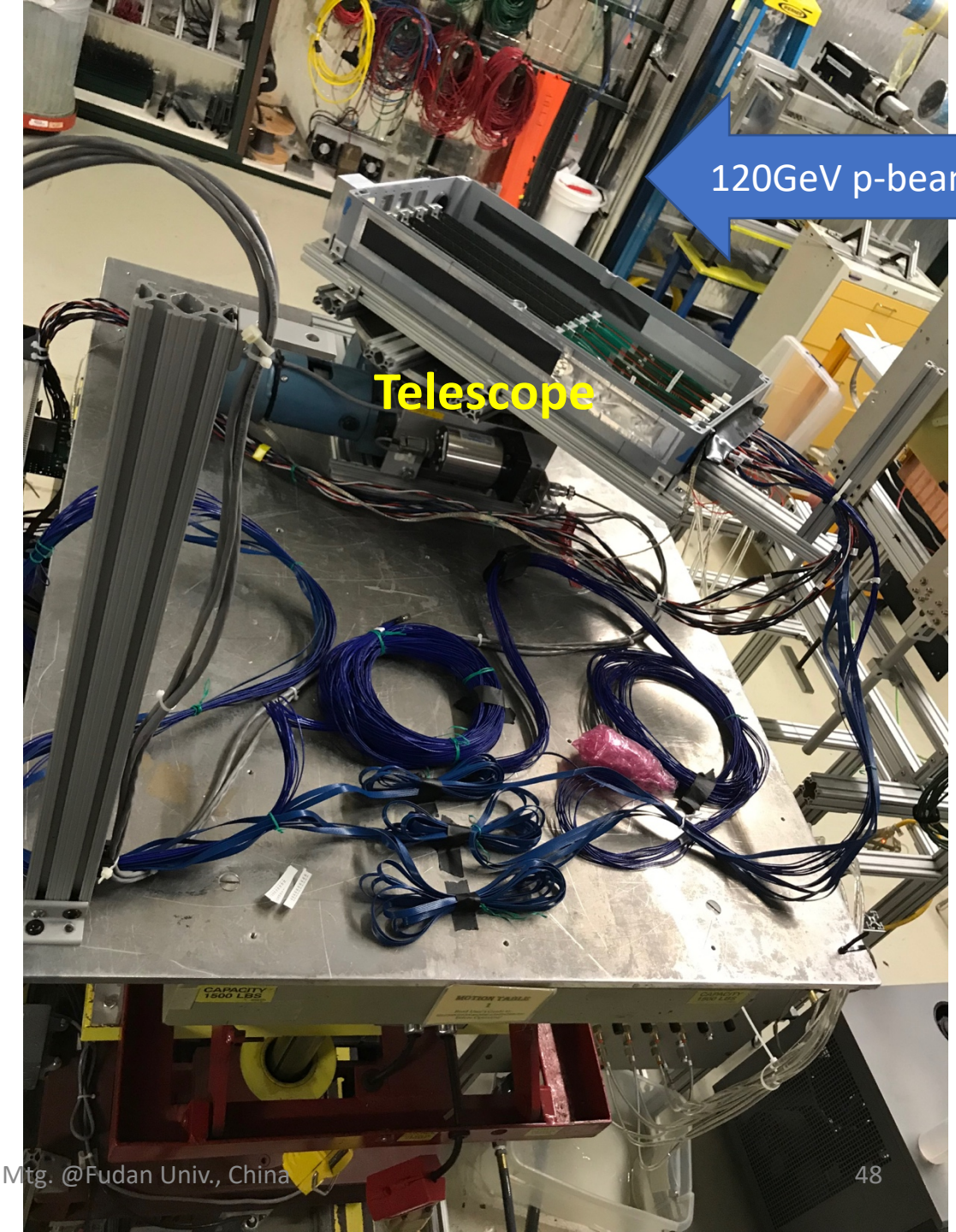


Staves, RUs, PU etc.

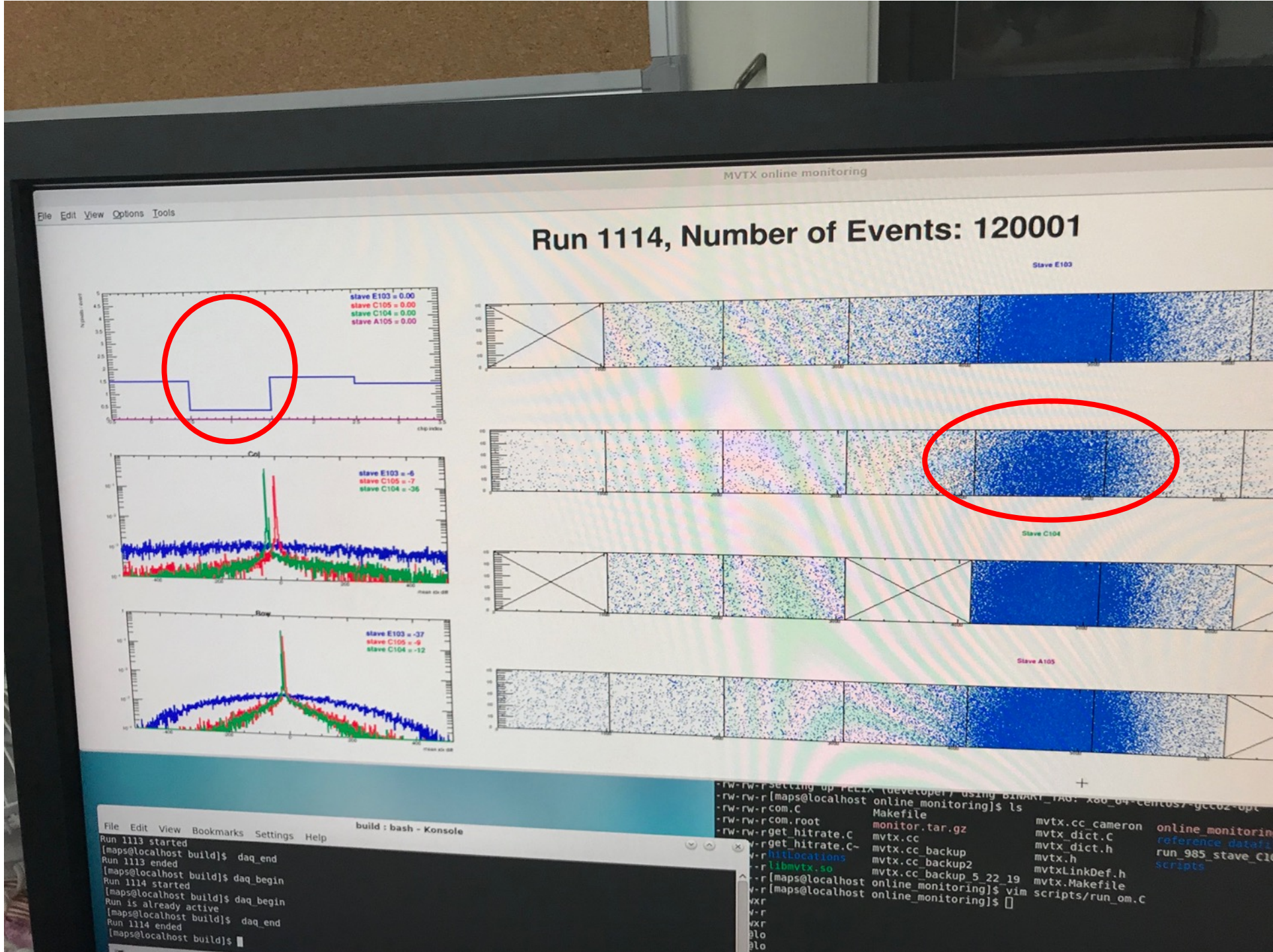




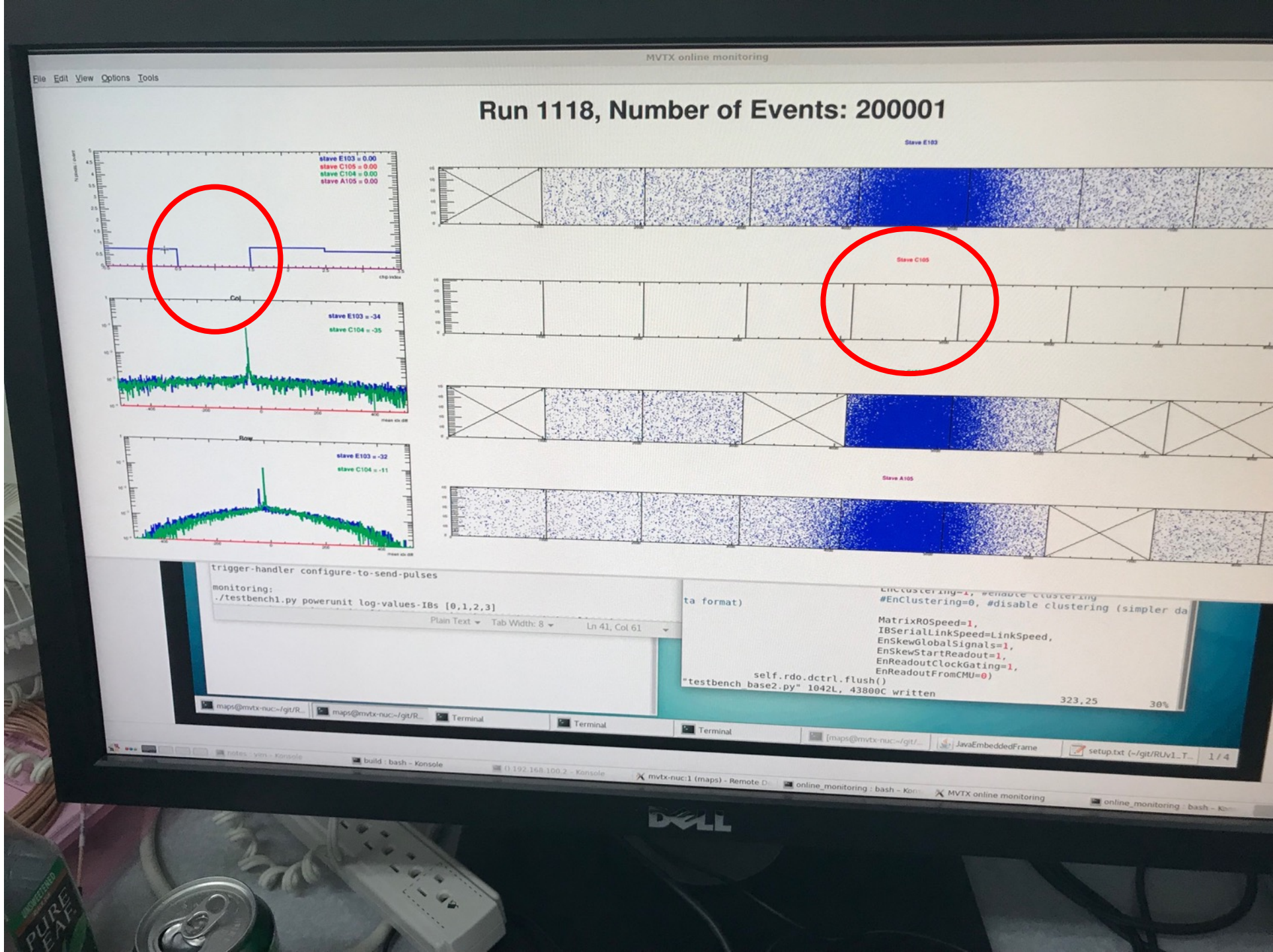

120GeV p-beam
Telescope
RUs & PU
Cooling System;
negative pressure
@-30%ATMP (-5PSI)


120GeV p-beam
Telescope

When MAPS parameters off the optimal point, less hits collected



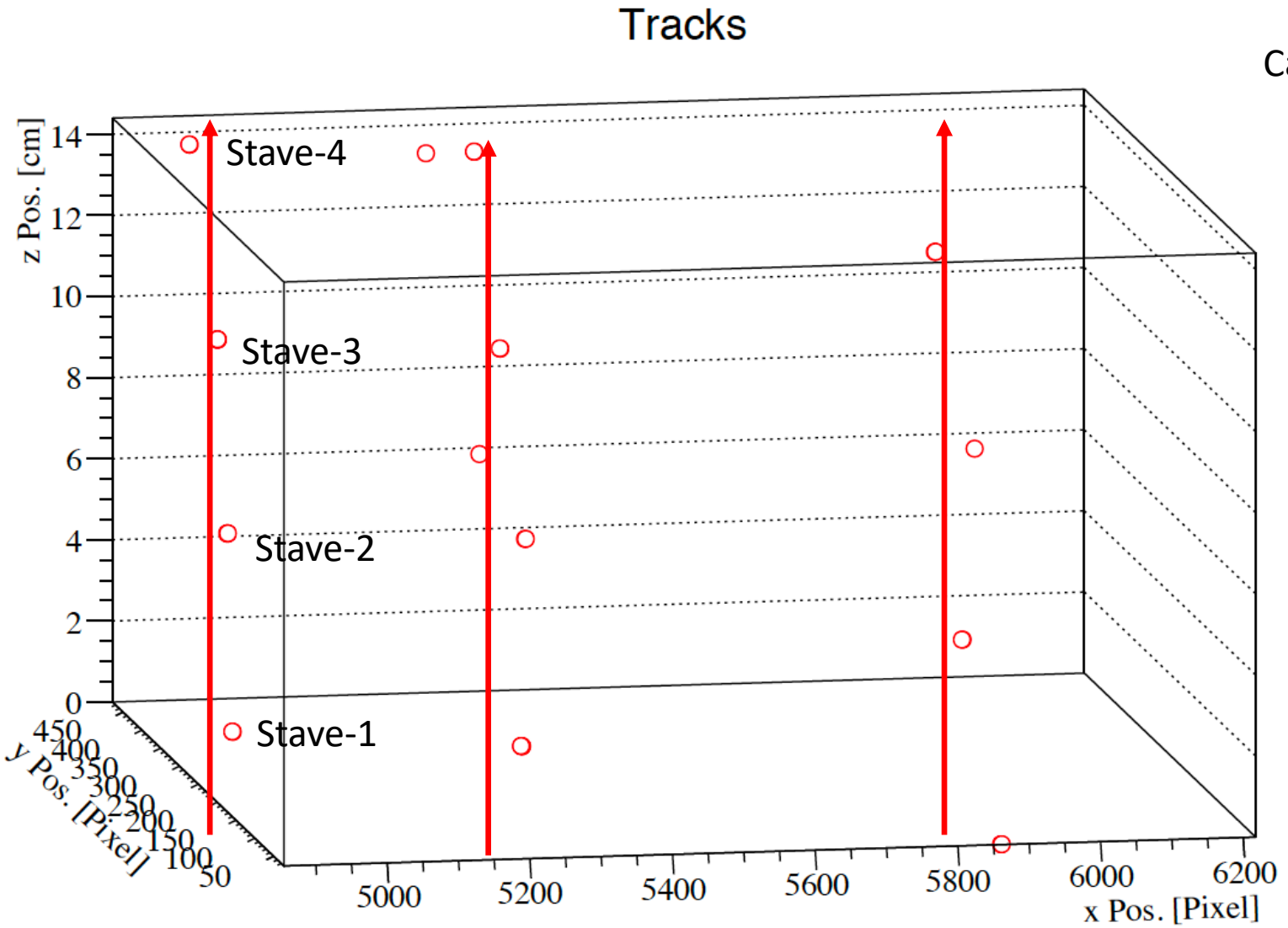
No hits seen when MAPS parameters far-off the optimal point



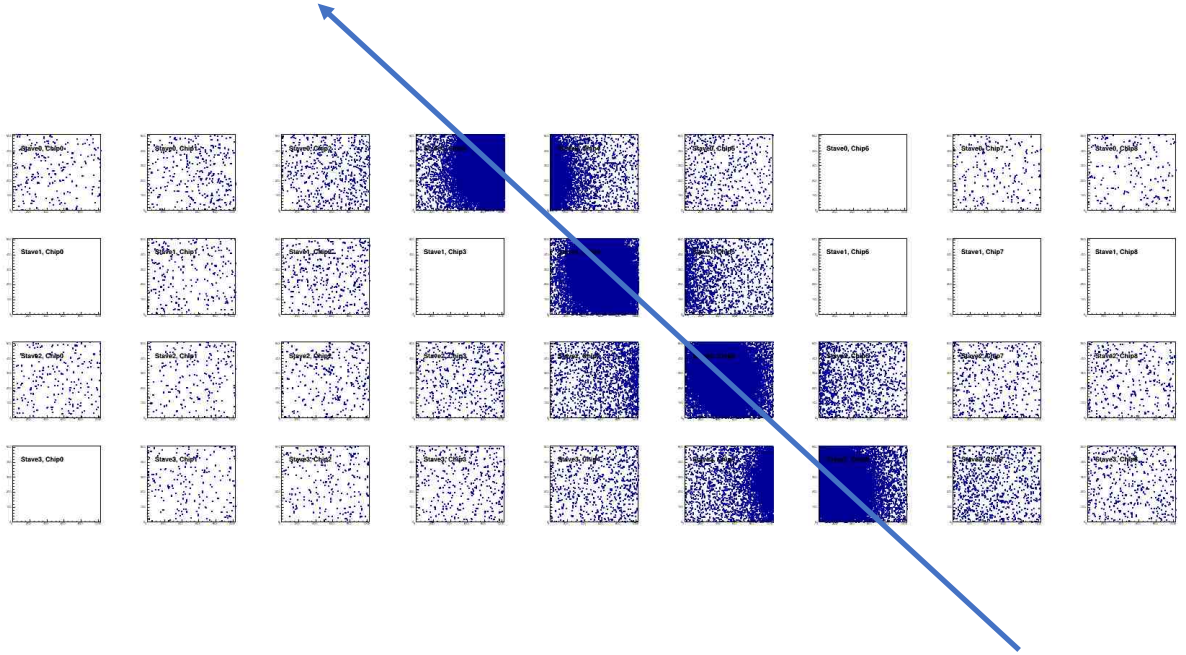
Installation

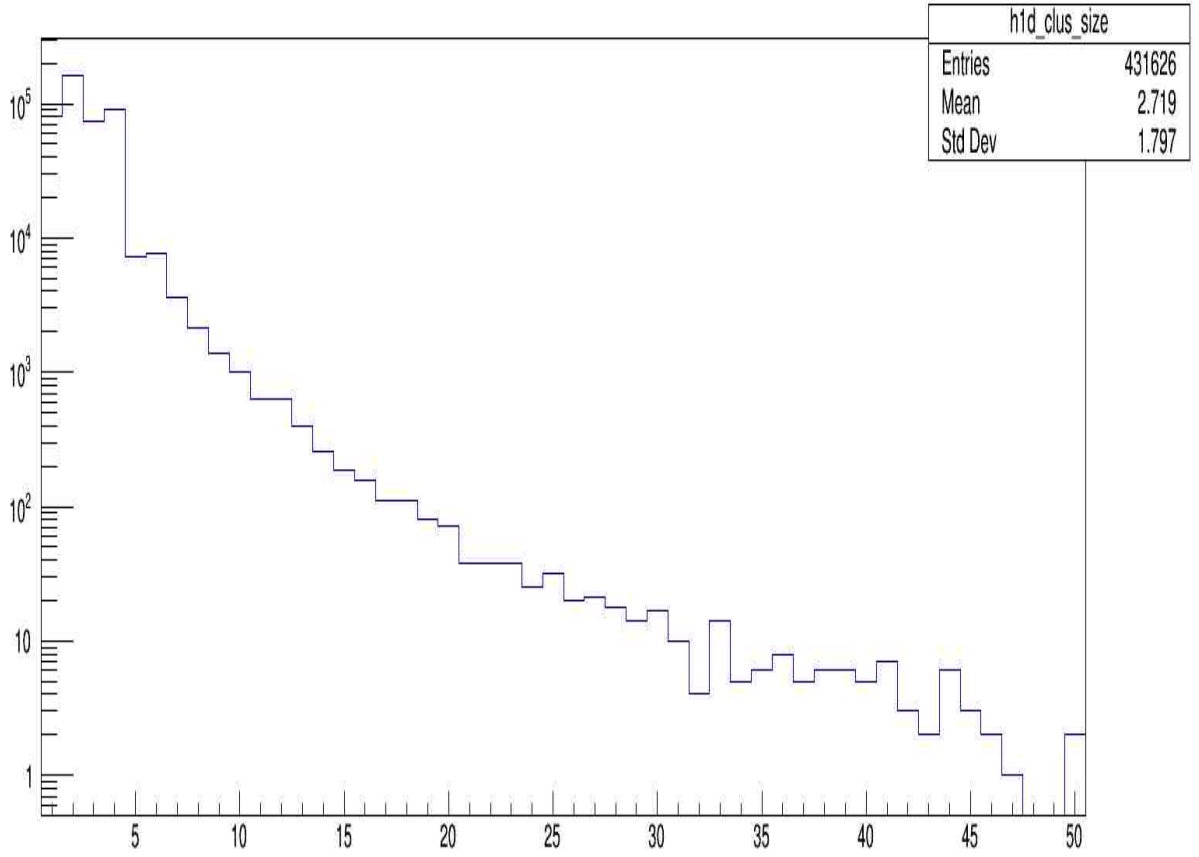
3-D event Display: p+Pb collision

Cameron



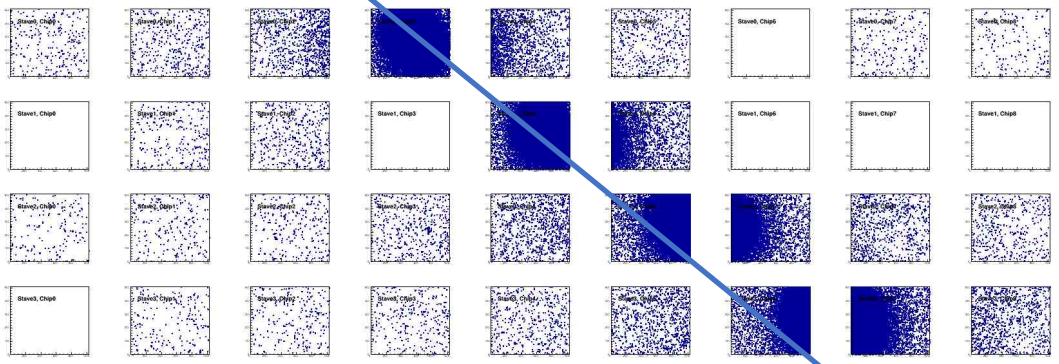
Offline Analysis: Cluster size vs Angle
Run 877, angle – 30 dgr



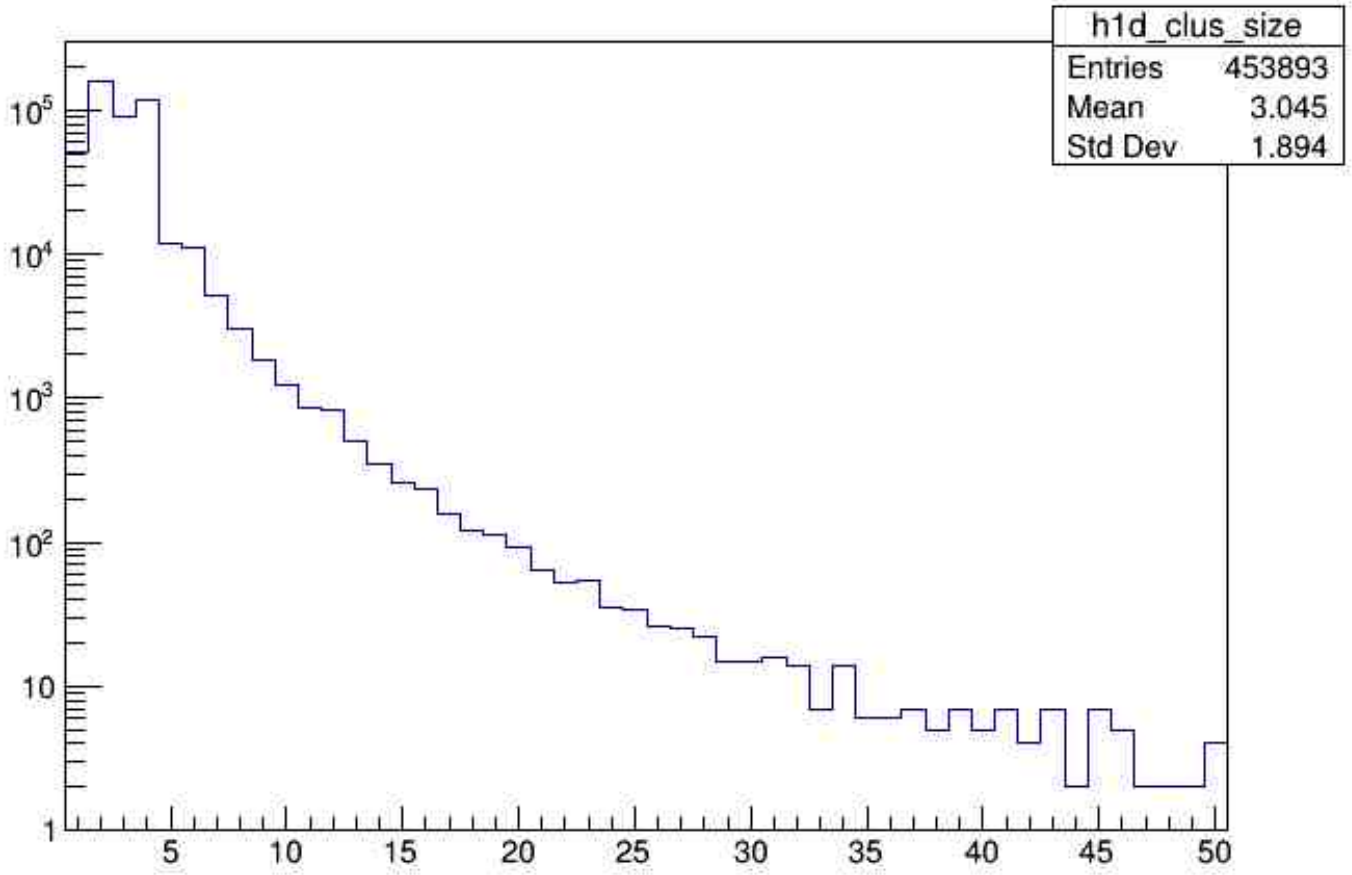


Cluster Size = 2.7

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



Cluster Size ~ 3.0



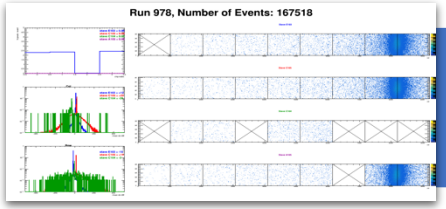
More work follows by Yasser, Sanghoon et al
Everyone is welcome to join the effort!

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

Run Types – Details being documented in MVTX wiki

From Xiaochun

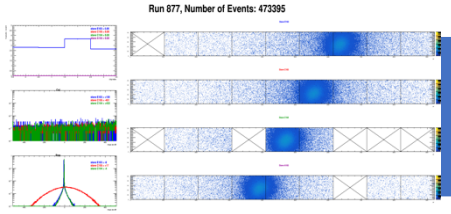
Run0978



Horizontal stave scans (many good runs)

Vertical stave scans

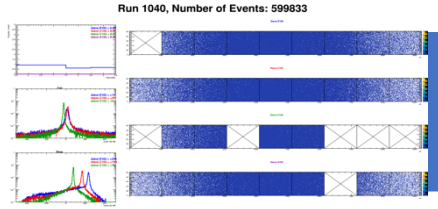
Run0877



Angular stave scans and tilted runs

Extruded aluminum & Lead-block runs

Run1040



Electron beam at 5 GeV (one long run)

LongRunList

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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