MVTX Status & Plan

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for the MVTX Group

MVTX/HF Workfest @MIT

Outline

- Project Status
- MVTX full proposal
  - Physics and Simulations
  - Readout and Controls
  - Mechanical Integration
  - Budget and Schedule
- R&D Highlights
- Latest development

MVTX Status: Where do we stand?

- Full proposal submitted to BNL Associate Laboratory Director Dr. Berndt Mueller in Feb. 2018

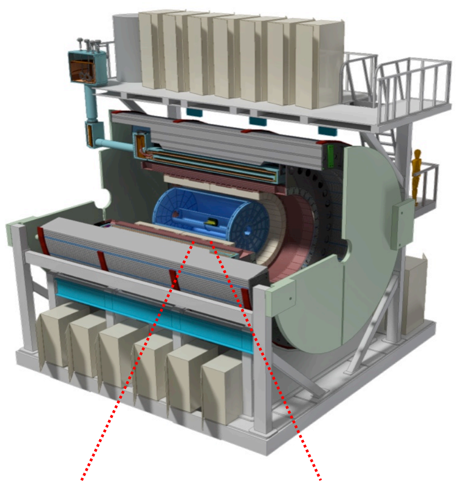
- March 27, a meeting of ALD, MVTX principals, co-SP and sPHENIX project office. Given improved DOE funding fiscal outlook, ALD recommended to bring MVTX into MIE baseline:
  - This would be post-OPC/CD-1 Review(5/23-25, 2018), MIE baseline will be defined in the CD-2 (~summer 2019); MS Project -> P6 in progress
  - Exploring advance-funding options to procure Readout Units ($250K, now) and staves from ALICE at CERN ($1.2M, fall 2018)
    - Cost saving and reduce technical and schedule risks
  - ALD seeks DOE agreement to proceed

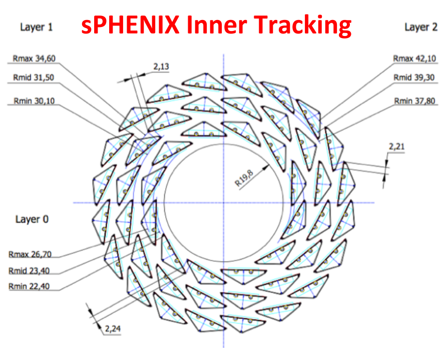
- MVTX workfest at MIT 4/30-5/1, 2018
  - Refine MVTX roadmap – cost & schedule etc
  - Prepare for sPHENIX integration mini review (~summer 18)
    - MVTX+INTT+TPC…
    - Both electrical and mechanical systems

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

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

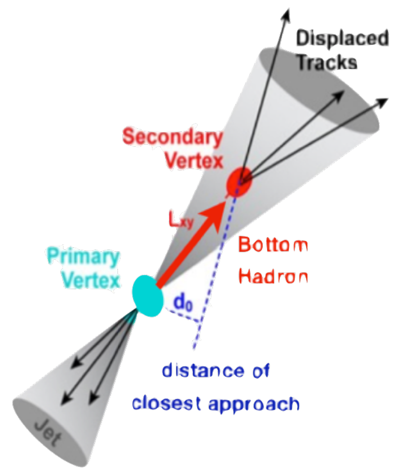
sPHENIX upgrade @RHIC



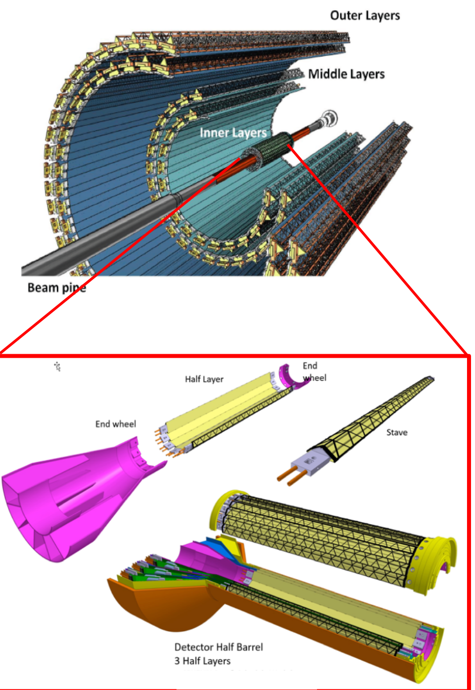


Key integration tasks:

- Readout
- Mechanics



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



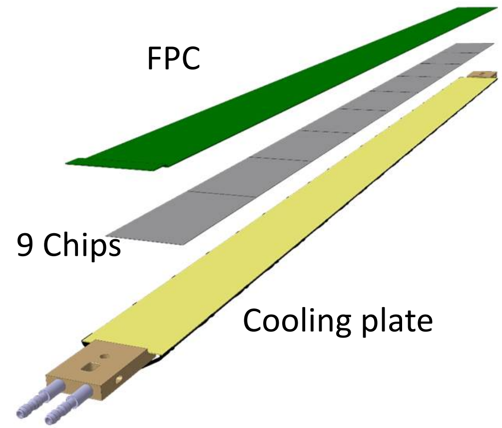
"Adopt" ALICE/ITS
Mini. risk,
Max. physics

MVTX could also be a day-1 EIC detector

Monolithic-Active-Pixel-Sensors (MAPS)

ALPIDE: The next Generation State of the Art Pixel Sensor

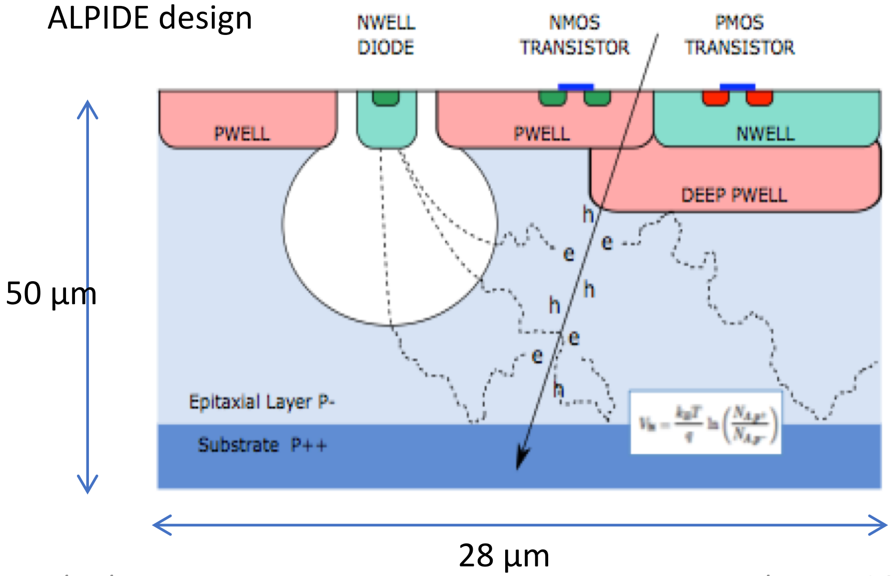
- **Advantages of ALICE MAPS(ALPIDE):**
  - Very fine pitch (27x29 µm)
  - High efficiency (>99%) and low noise ($<10^{-6}$)
  - Excellent time resolution, ~5 µs
  - Ultra-thin/low mass, 50µm (~0.3% X_0)
  - On-pixel digitization, low power dissipation



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

An ideal detector for sPHENIX and EIC physics!

ALPIDE design



Tower Jazz 0.18 µm CMOS

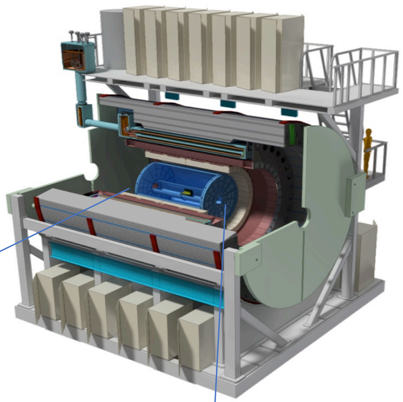
- feature size 180 nm
- metal layers 6
- gate oxide 3nm

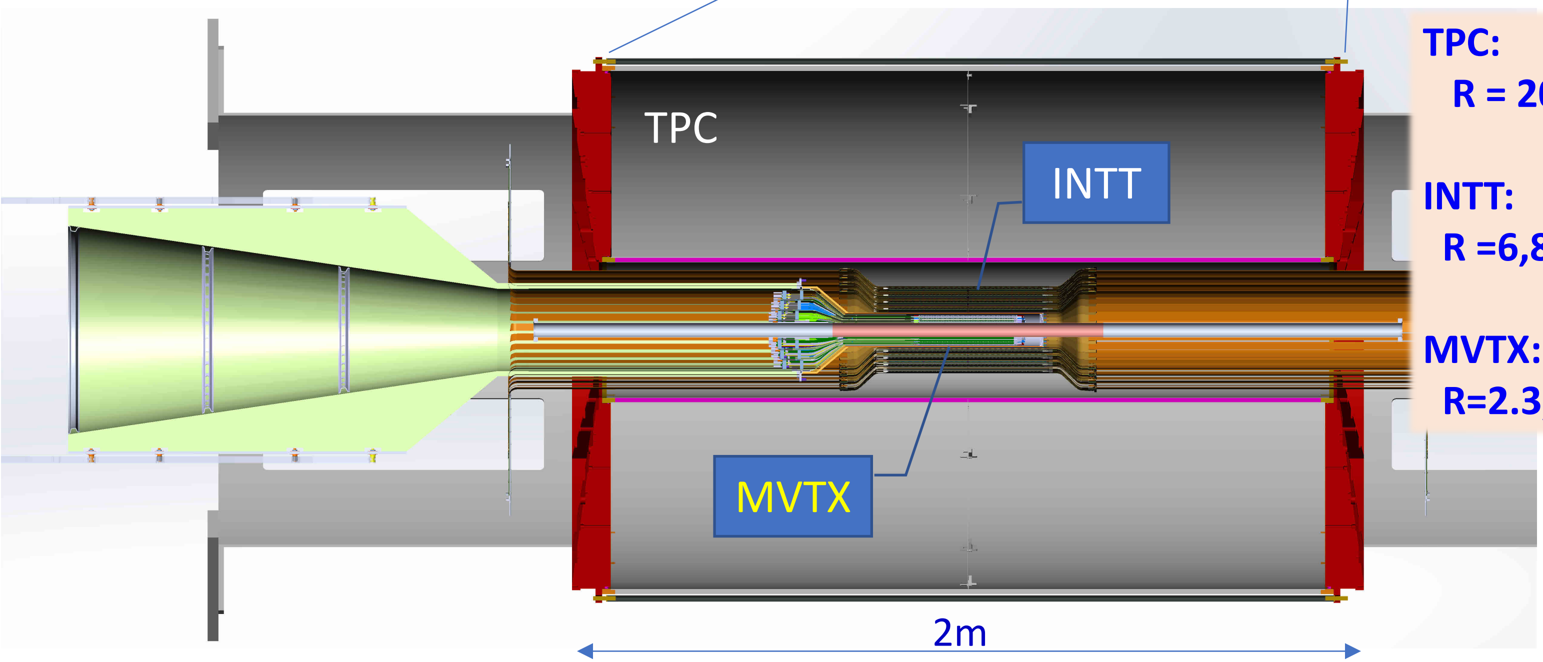
substrate:	$N_A \sim 10^{18}$
epitaxial layer:	$N_A \sim 10^{13}$
deep p-well:	$N_A \sim 10^{16}$

sPHENIX 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

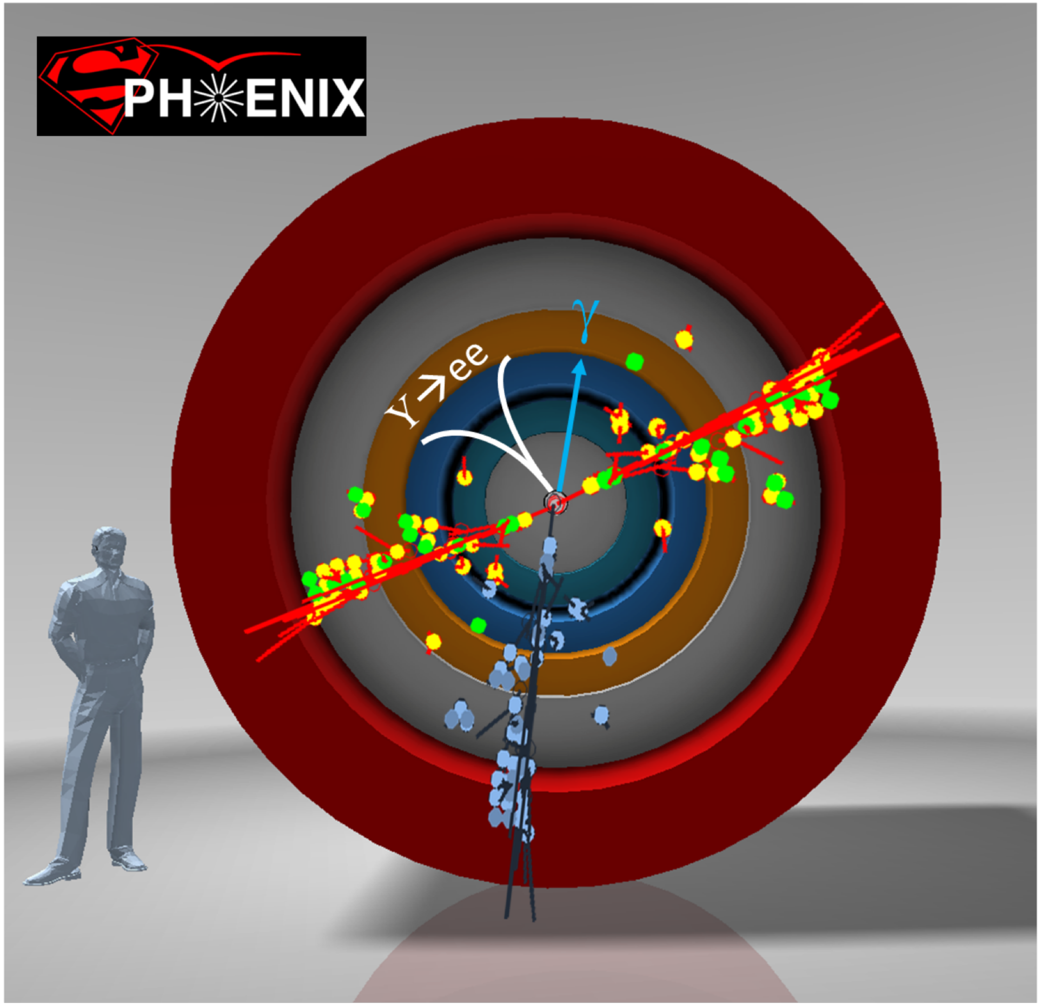
MVTX:
R=2.3, 3.2, 3.9cm

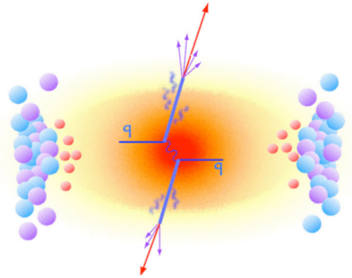
MVTX Enables the 3rd Science Pillar

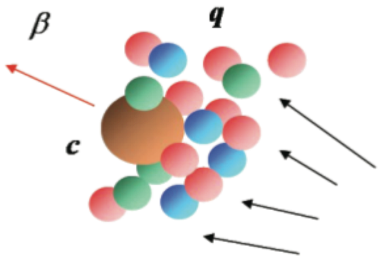
Xin's talk

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



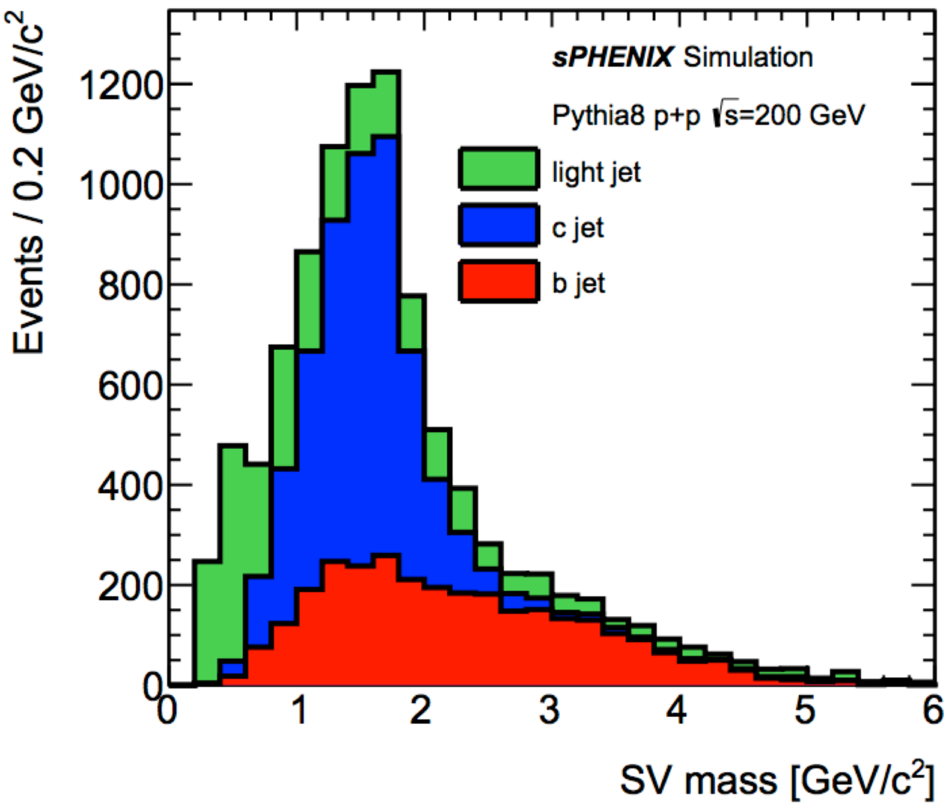


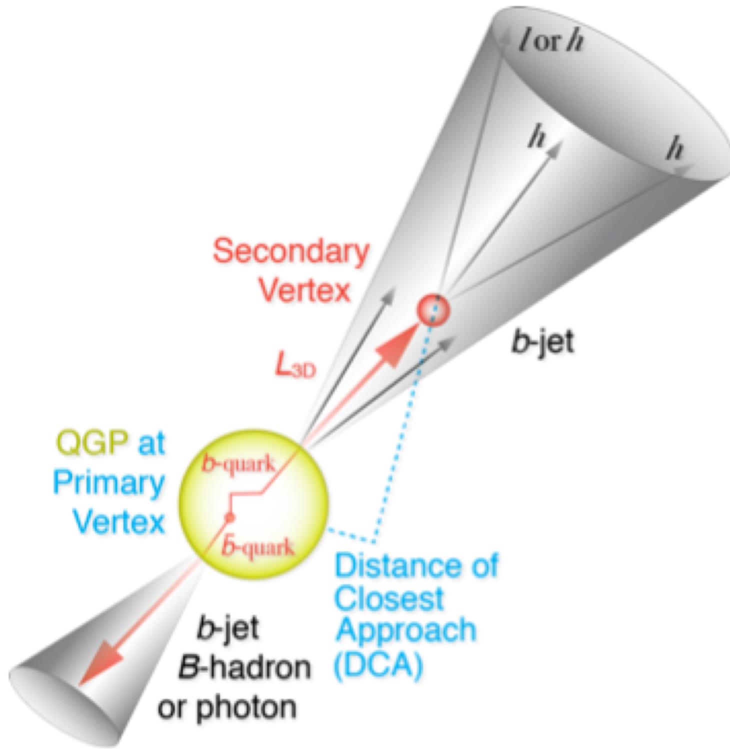


B-Hadron & b-Jet Tagging

Haiwang/Jin'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!**

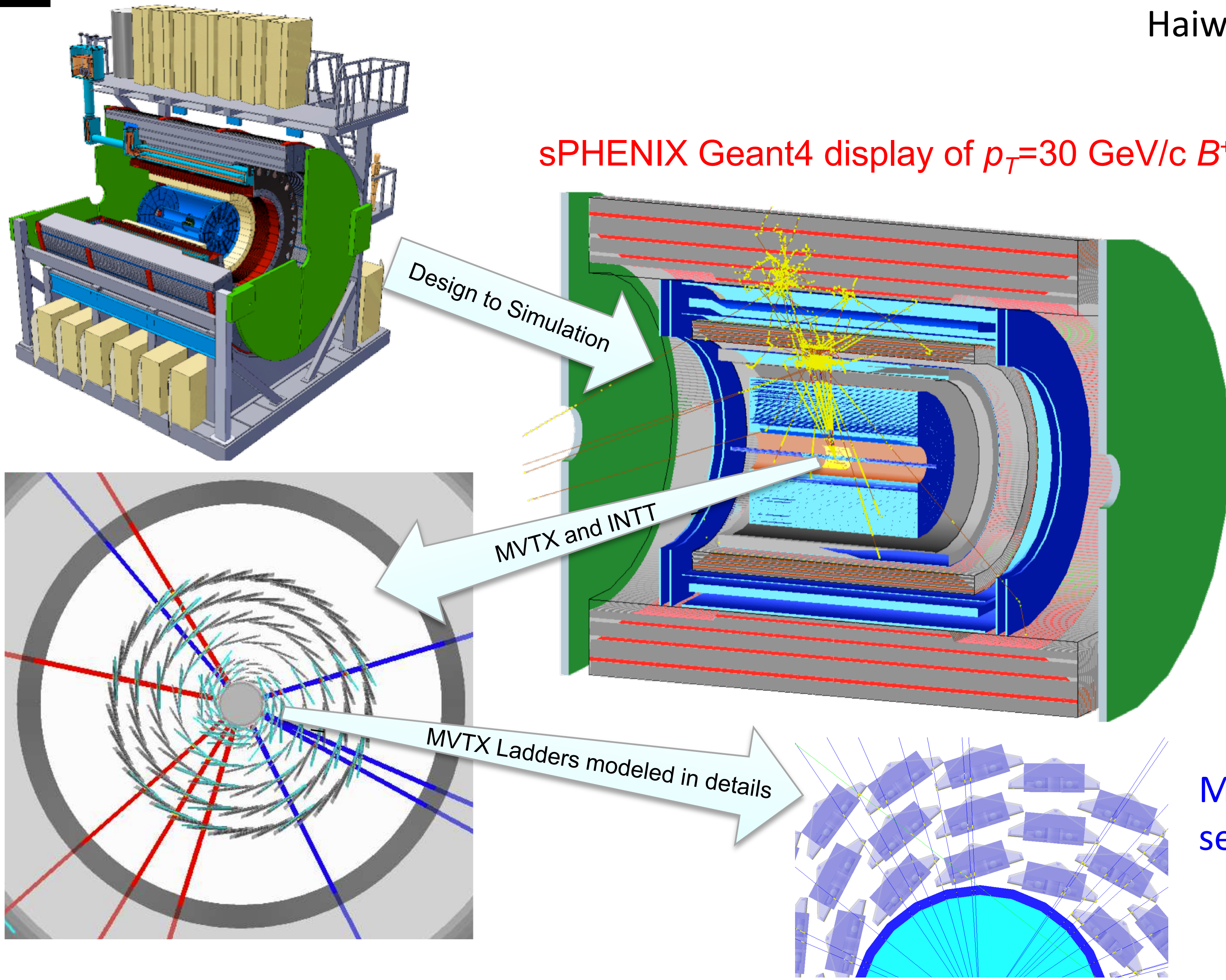




Simulation for *b*-jet and *B*-meson tagging

Haiwang's talk

sPHENIX Geant4 display of p_T=30 GeV/c B^+-hadron



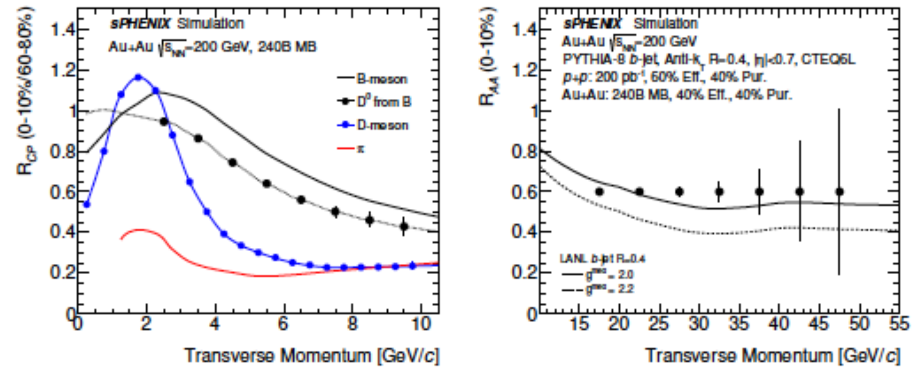
MVTX sensors

MVTX Physics Highlights

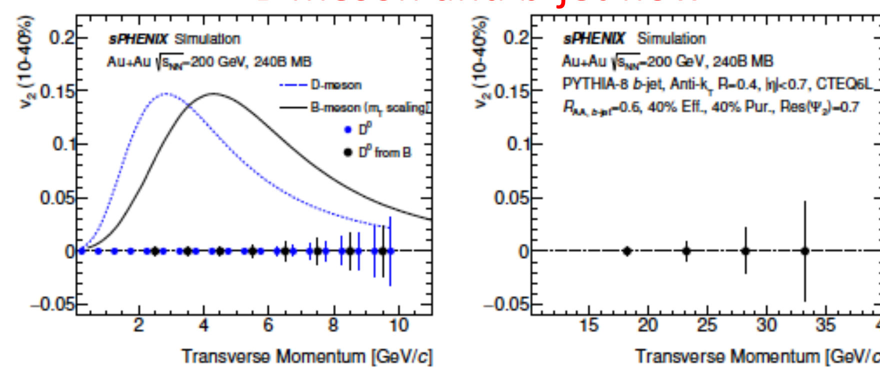
Xin's talk

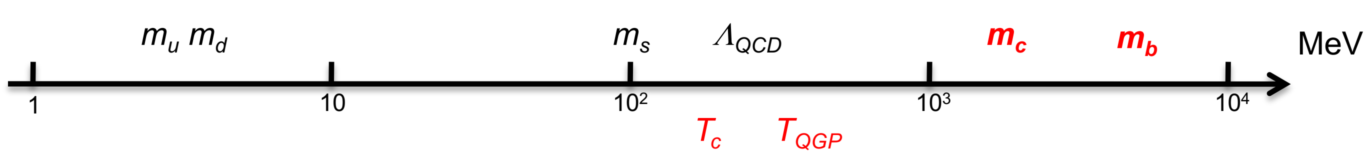
- Heavy quarks – unique probe of QGP w/ new scales, **m_c, m_b**
  - Study mass dependence
    - Jet quenching & energy loss
    - Flow – interaction with medium
  - Access QGP properties
    - Temperature, density, coupling, transport coefficients, viscosity etc.

"B meson and b-jet modification"



"B meson and b-jet flow"

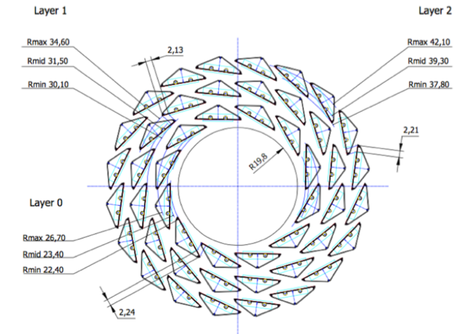




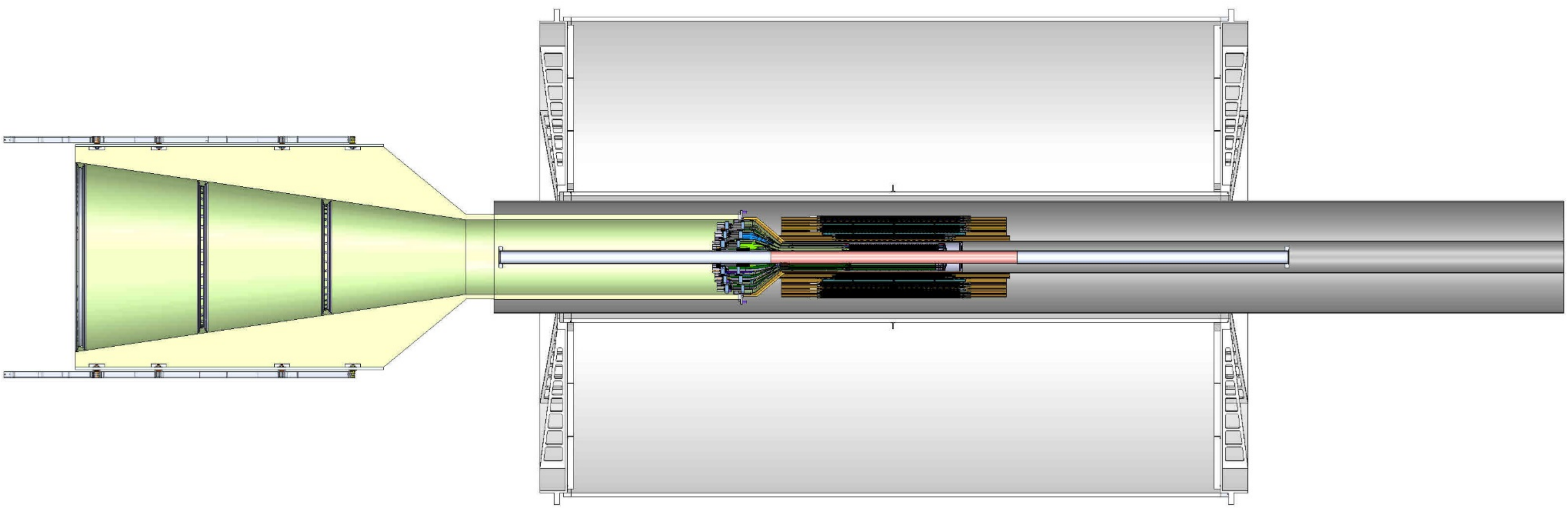
MVTX Detector Integration

Mickey/Walt's talks

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

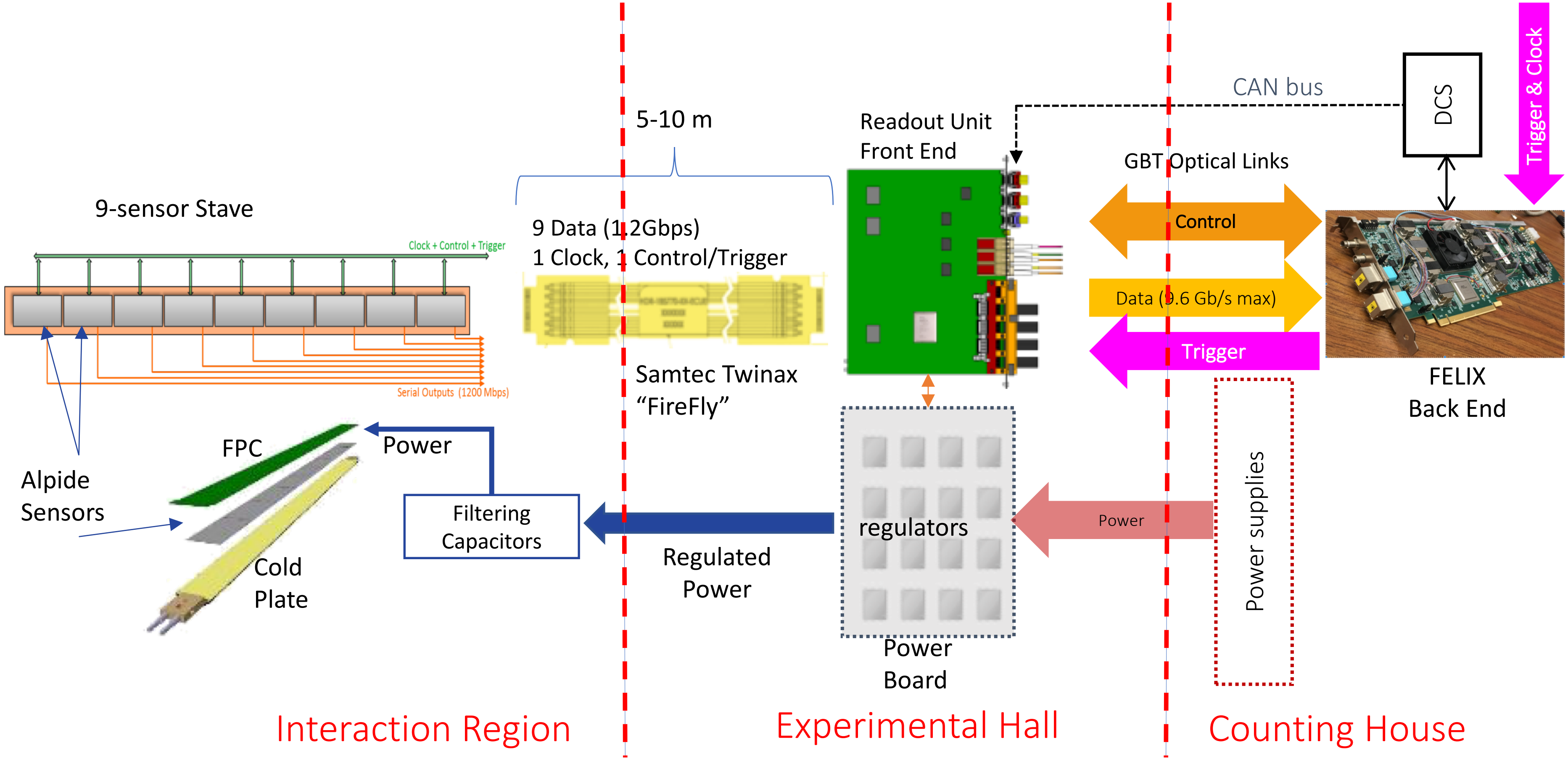


- Electrical system
  - Readout, power, controls
- Mechanical system
  - Support and cooling



Readout and Controls

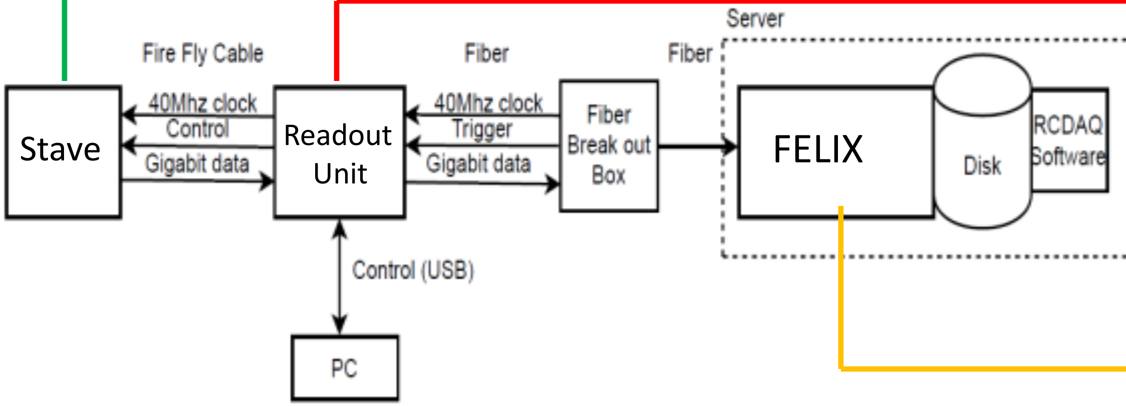
MVTX Electronics, Power and Controls



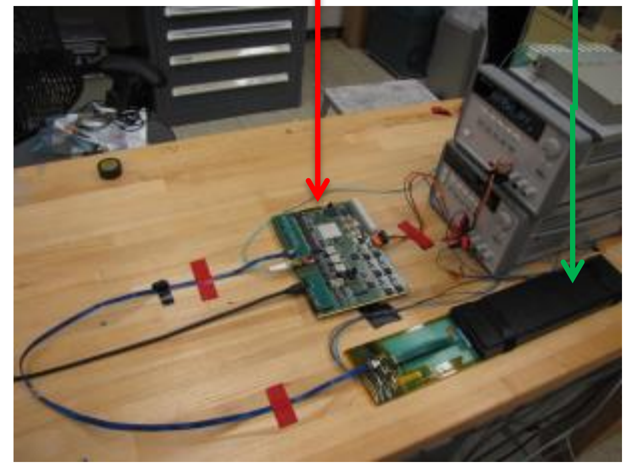
MVTX Detector Electronics consists of three parts

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

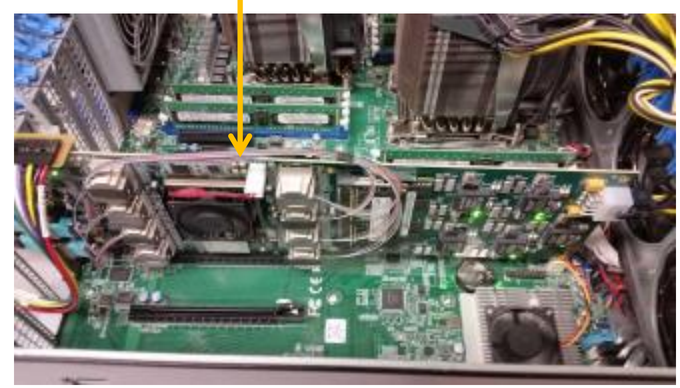
MVTX Full Readout Chain Demonstrated



- Readout Unit 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



Readout Unit + Stave



Server + FELIX

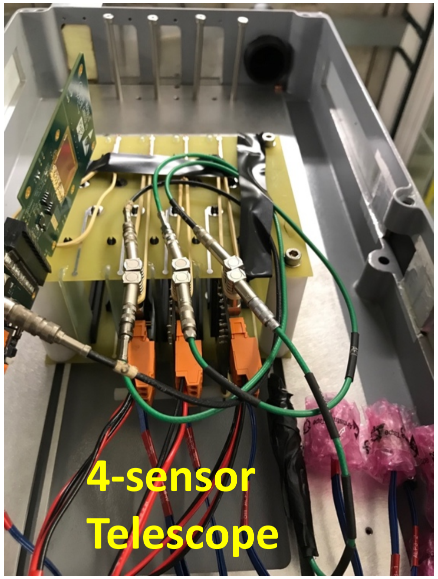
Amazing work done by Sho & Alex + LANL LDRD team!

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

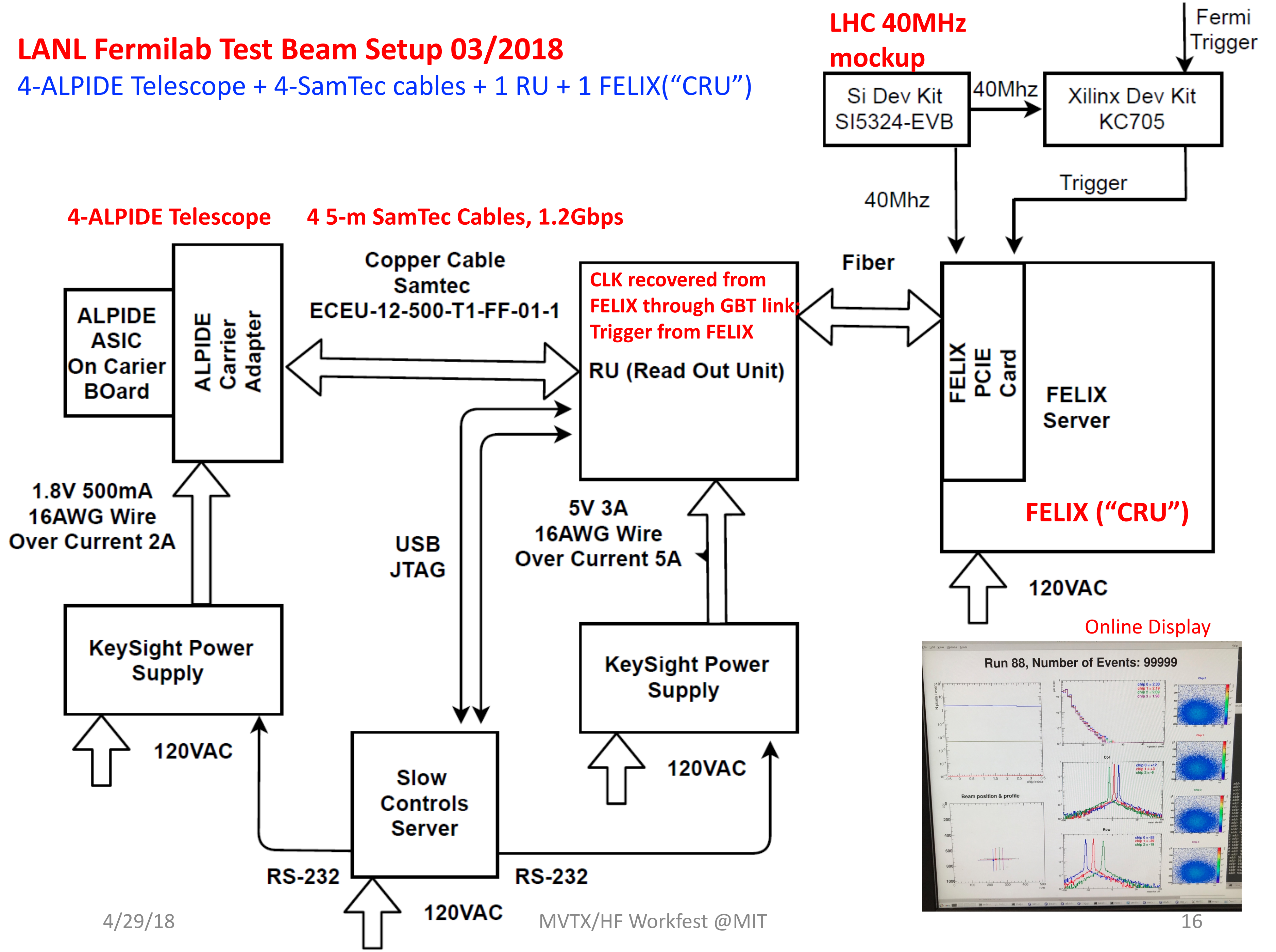
- Parasitic with INTT run
- Very productive & collaborative

120 GeV proton

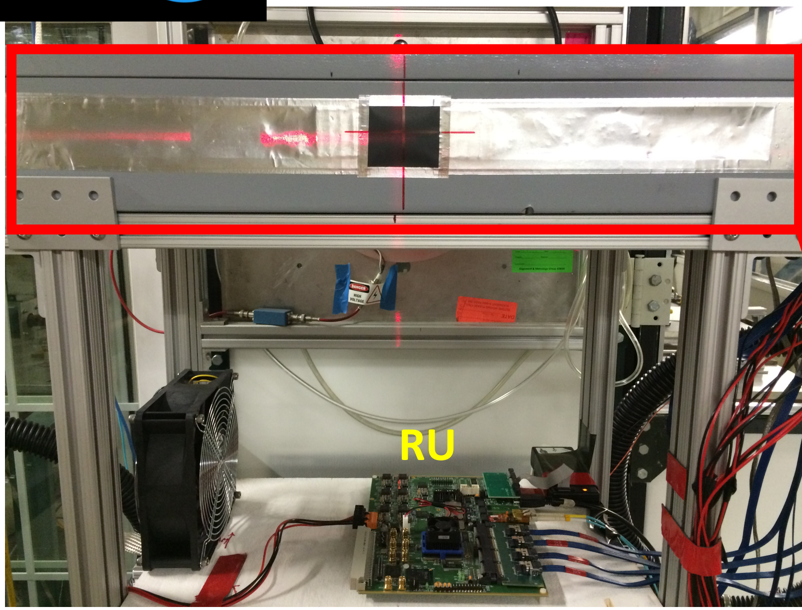


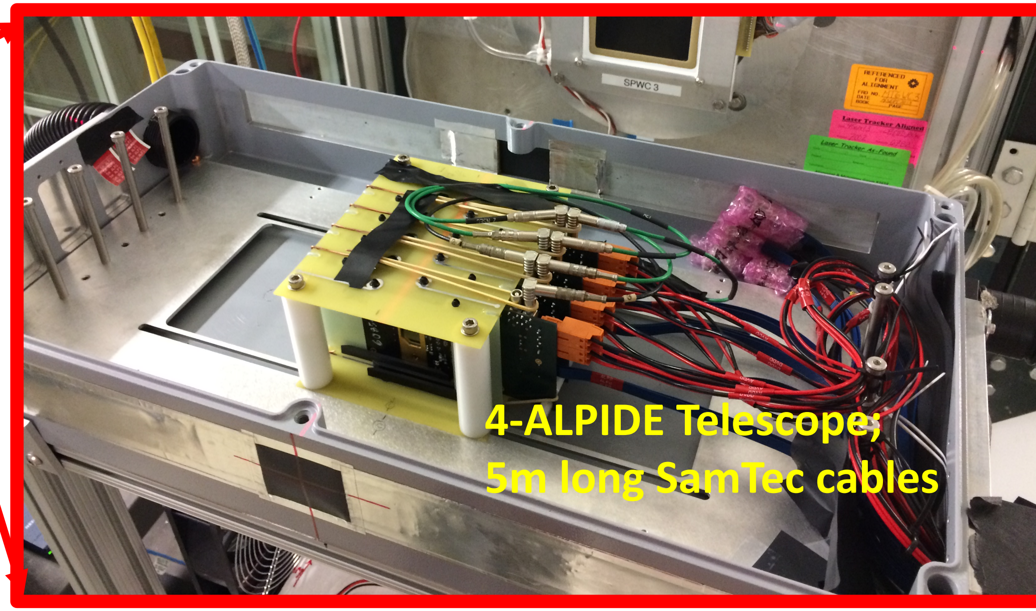
LANL Fermilab Test Beam Setup 03/2018

4-ALPIDE Telescope + 4-SamTec cables + 1 RU + 1 FELIX(“CRU”)



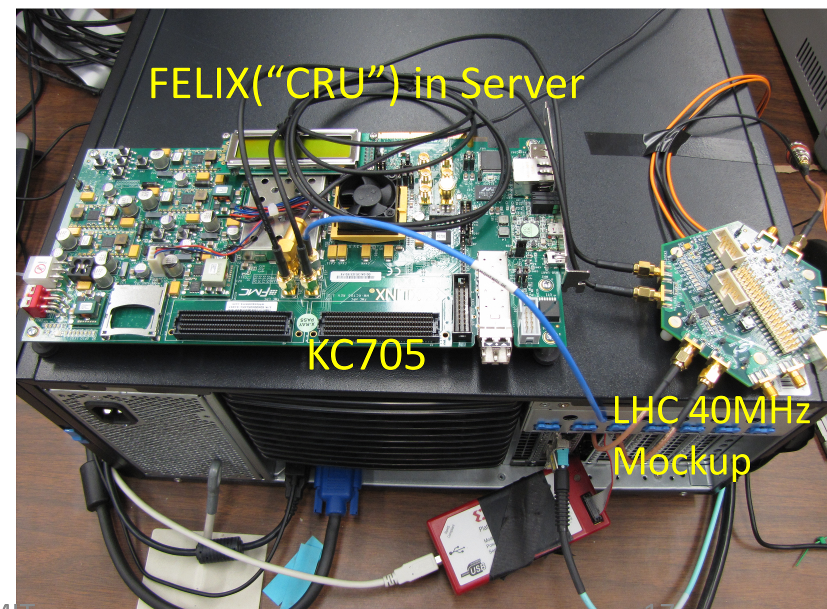
4-ALPIDE Telescope Setup at Fermilab Test Beam





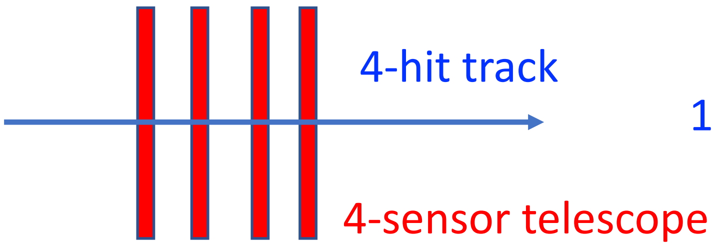
Summary:
- Successfully operated the full readout chain
- Confirmed all communications links and data path
- Confirmed telescope performance
  - Primarily 120GeV proton beam; also with low energy pion beams
  - Beam trigger rate ~7kHz
  - Tested High ALPIDE occupancy runs, with 10cm lead bricks in front of the sensors

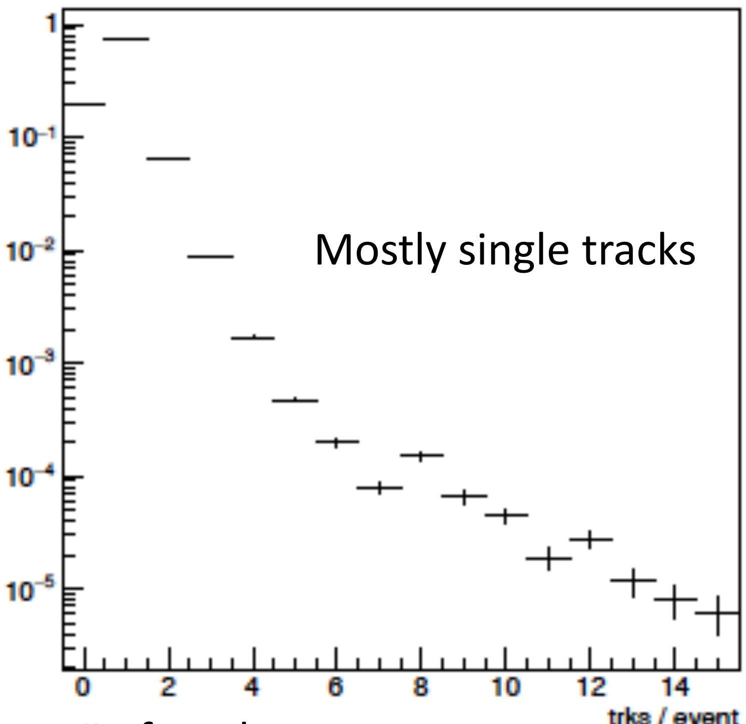
Nice work by Sho, Alex, Hubert, Chris + others



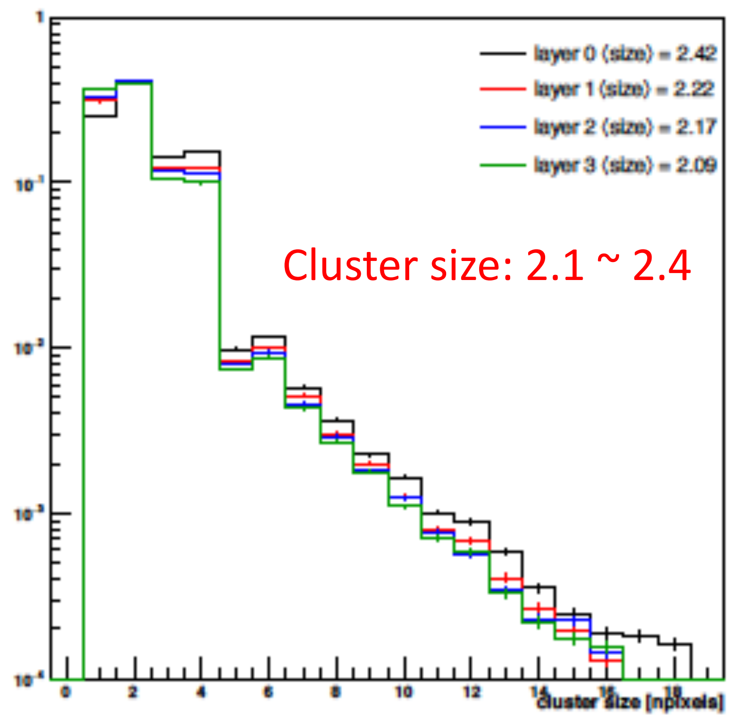
sPHENIX

Fermilab Test Beam Results (I)





# of tracks per event

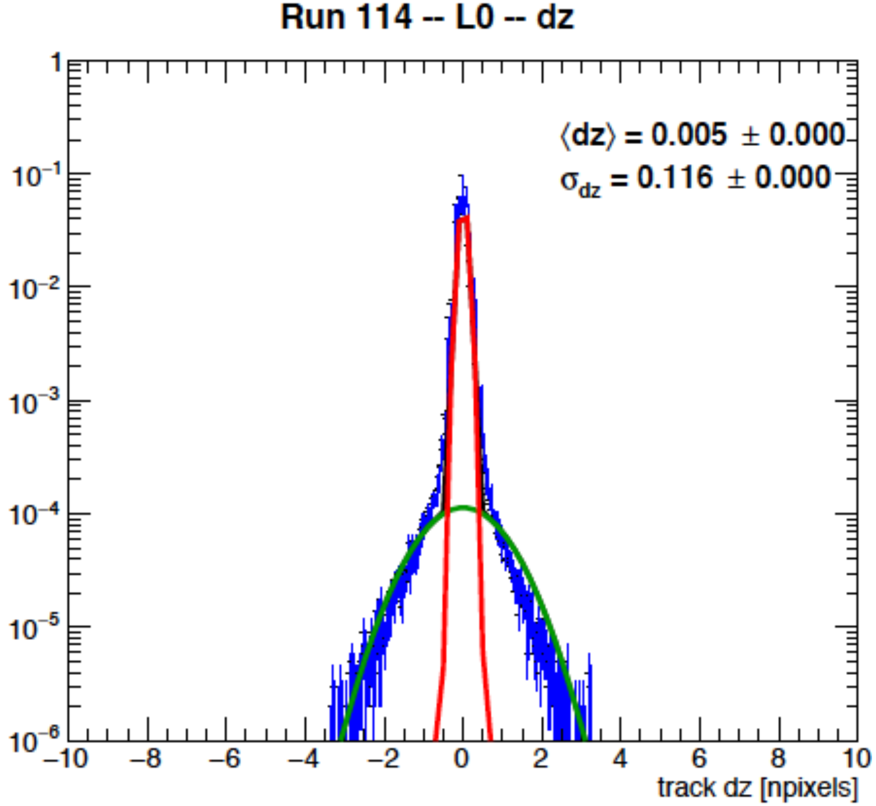


Cluster size

Beautiful analysis done by Sanghoon and Darren + others

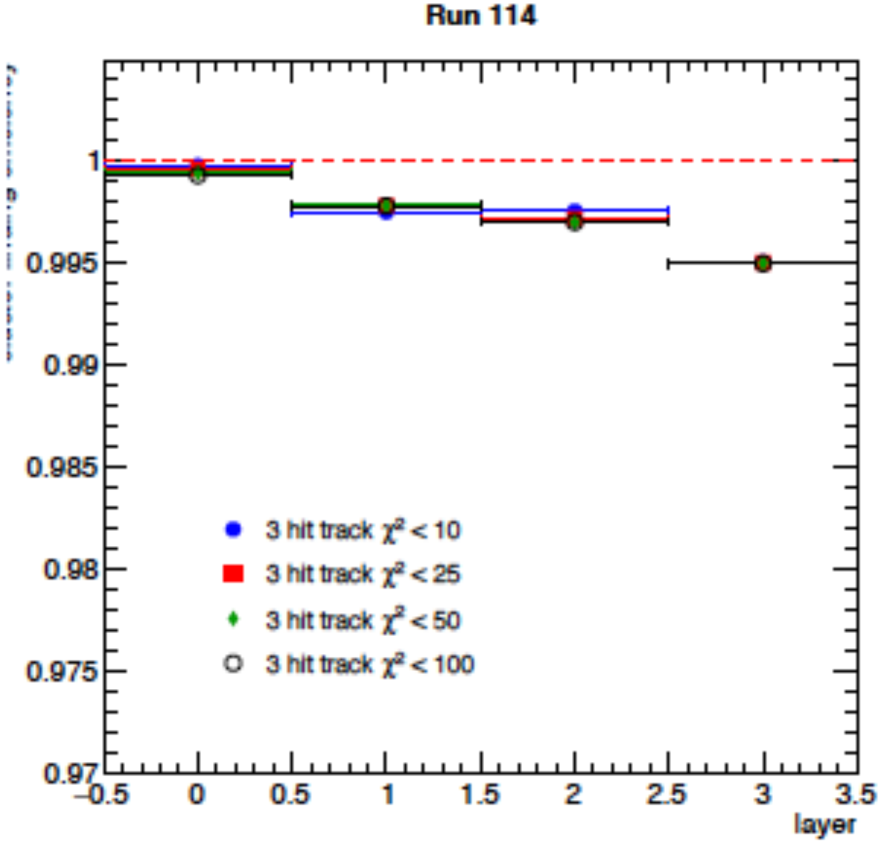
Fermilab Test Beam Results (II)

Hit Spatial Resolution: < 5 um



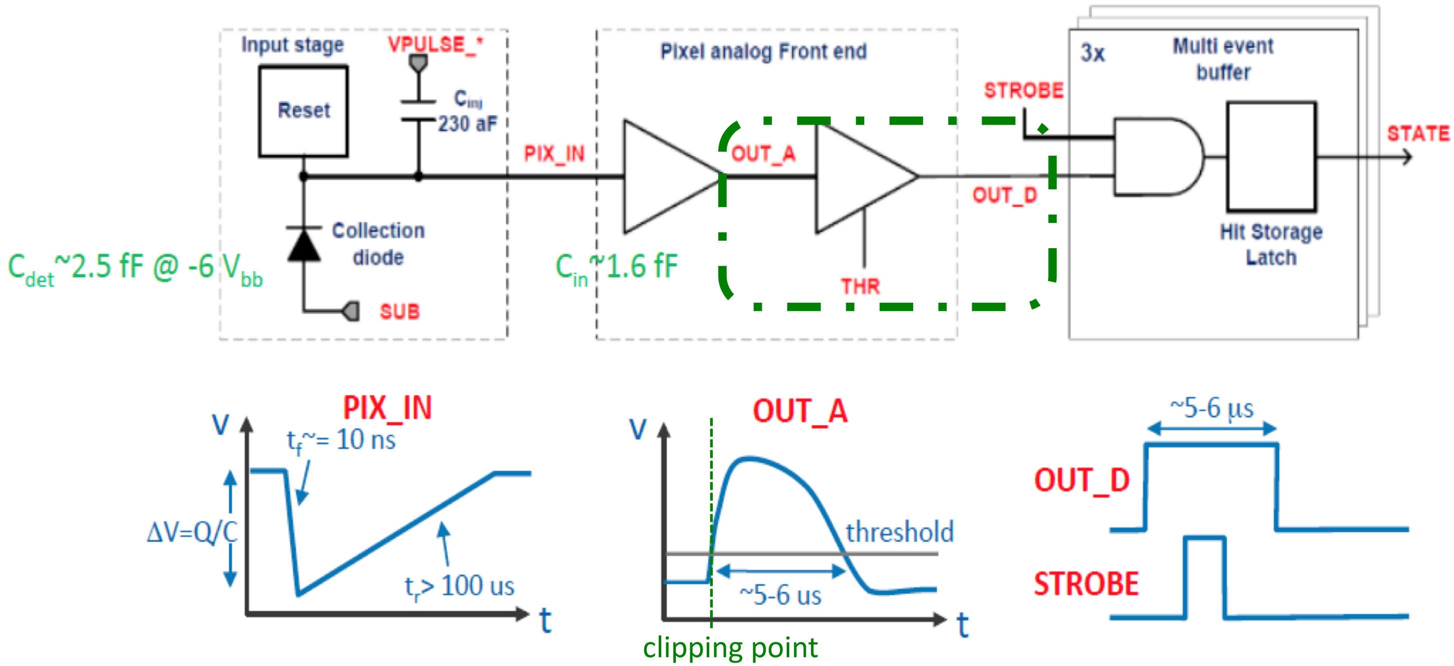
Pixel size (~28um)

Hit Efficiency > 99.5%



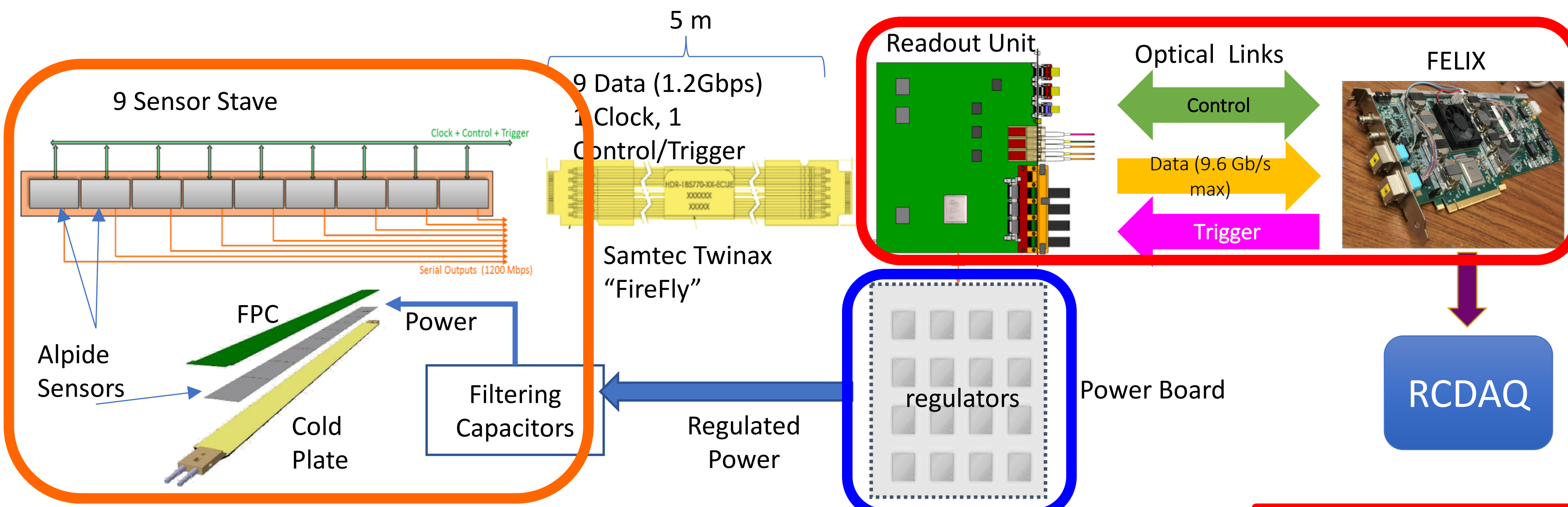
ALPIDE Readout Optimization and Trigger Latency Study

- Expected sPHENIX trigger latency 4~5 uS
- Two possible readout modes for MVTX: 1) Triggered (less data) and 2)Continuous

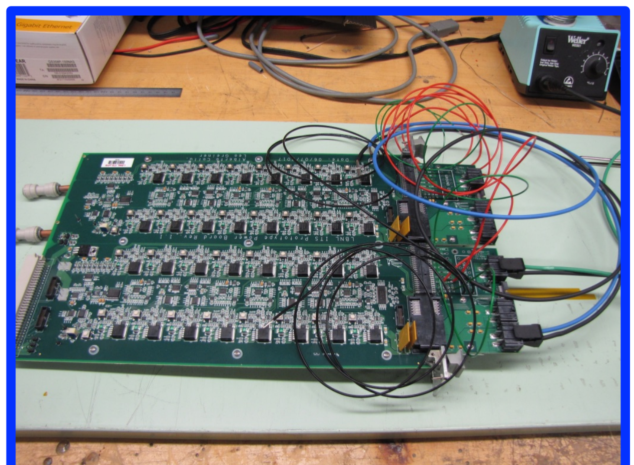


- OUT_A clipping: VCLIP. Decreasing VCLIP decreases clipping point.
- OUT_A returns to baseline time: ITHR, VCLIP. Increasing ITHR decreases discharge time, and decreasing VCLIP decreases discharge time after clipping.
- OUT_D return to baseline time: IDB. Increasing IDB increasing charging time hence decreasing pulse duration.

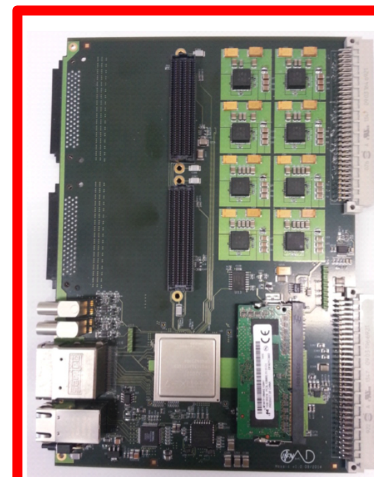
A Test Bench at LANL



One HIC and 5+ individual ALPIDE chips.



Power Board

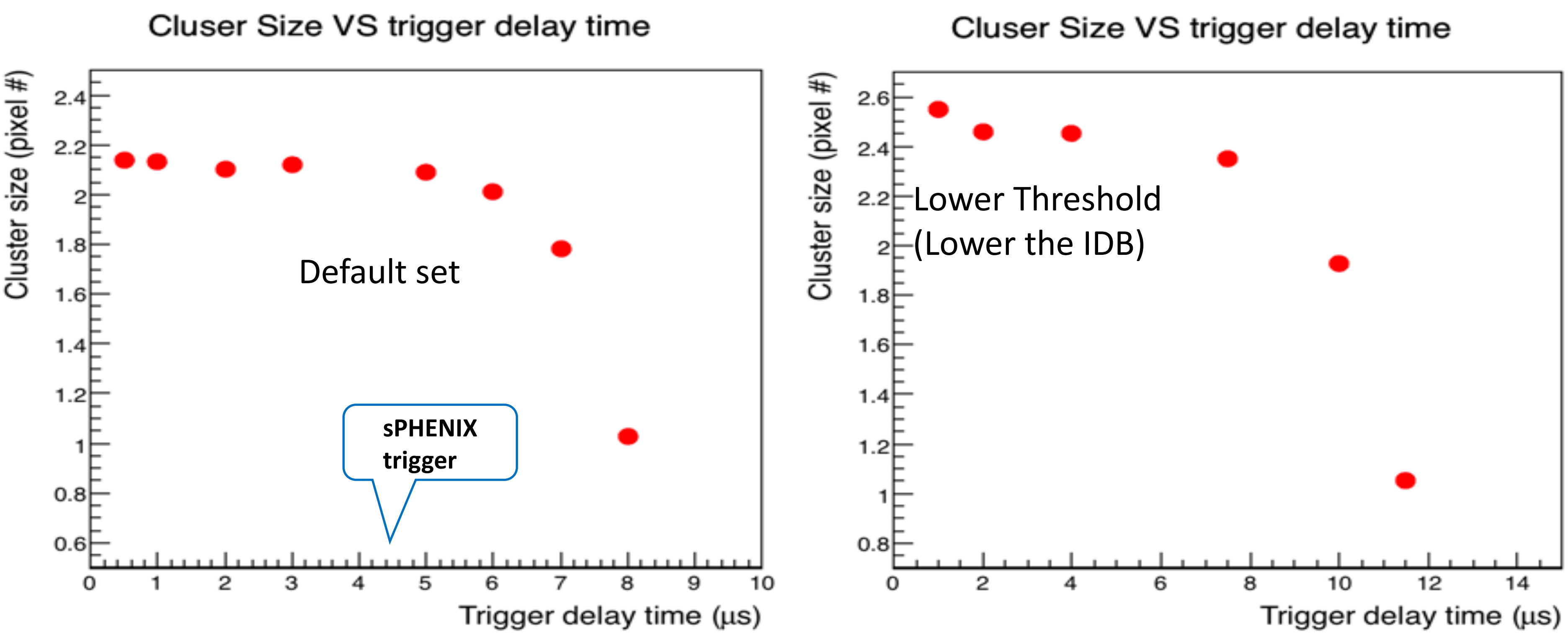


MOSAIC miniDAQ

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

To Do List

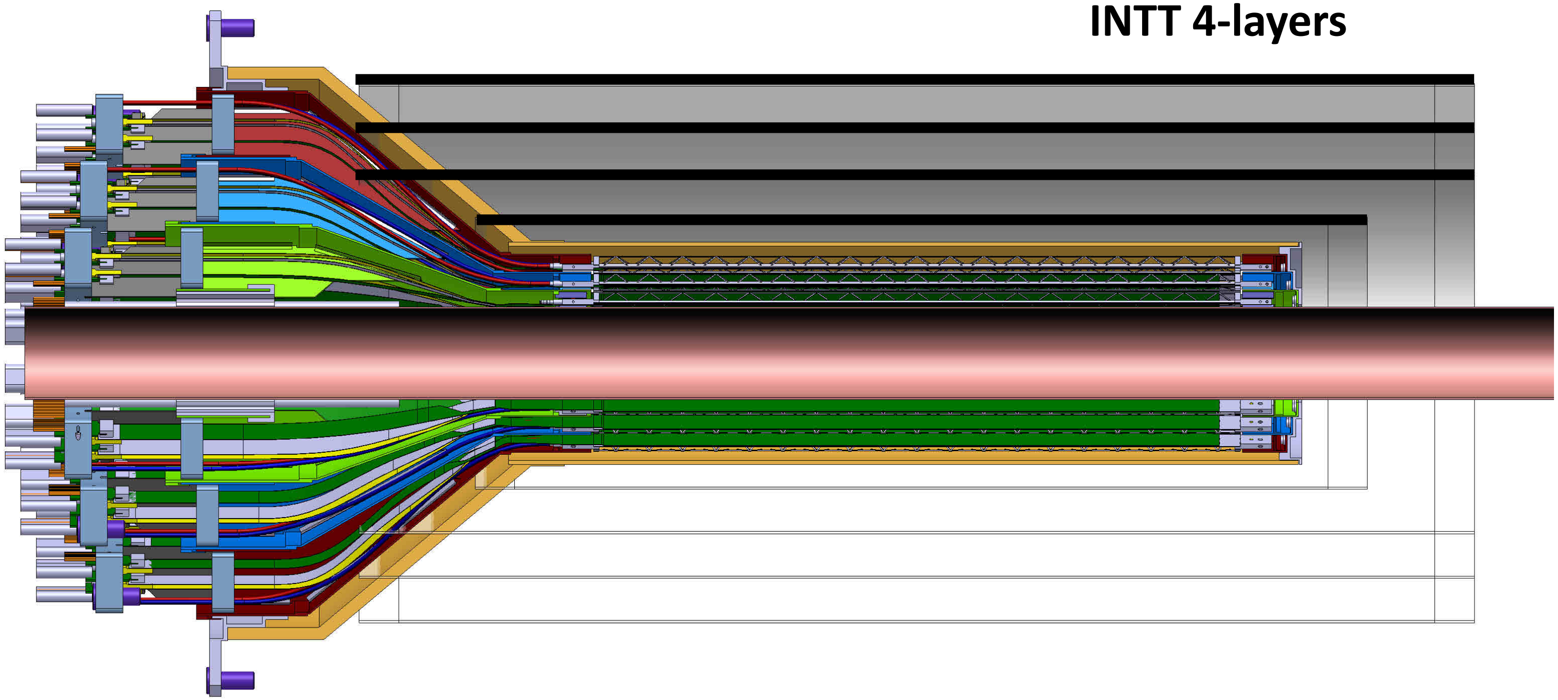
- Update firmware, sync with latest ALICE firmware
  - Scrubbing etc.
  - Burn-in test, stability
- Detector Control System (DCS) integration
  - Power distribution and monitoring
  - LV, “HV” and temperature
- Sensor operation optimization
  - Scan parameters for optimal operation
  - Laser test bench setup at LANL
- Multi-stave readout
  - Up to 3 staves per RU
  - Default: 1 stave per RU

sPHENIX System Integration

Walt's talk

INTT-MVTX Space Conflict

INTT Acceptance
@ |z|=10



|η|<0.95

|η|<1.09

|η|<1.28

|η|<1.12

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

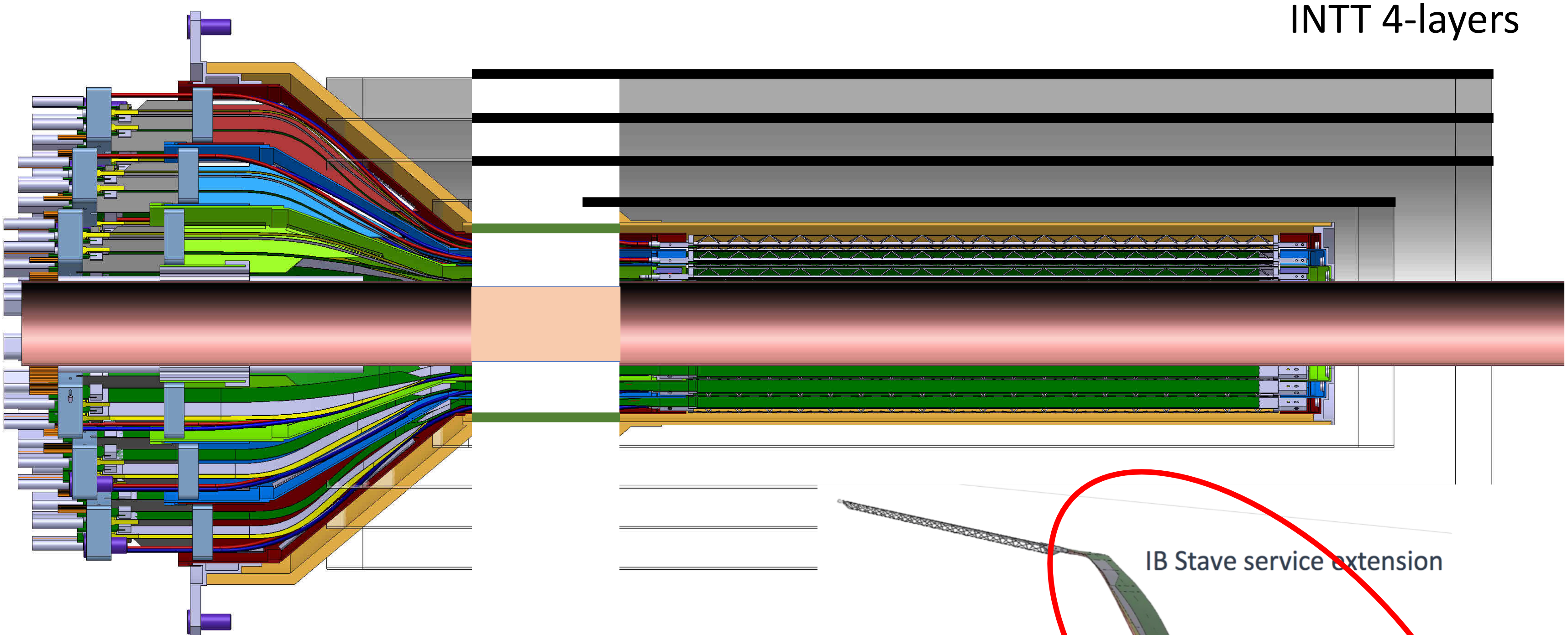
R&D items:

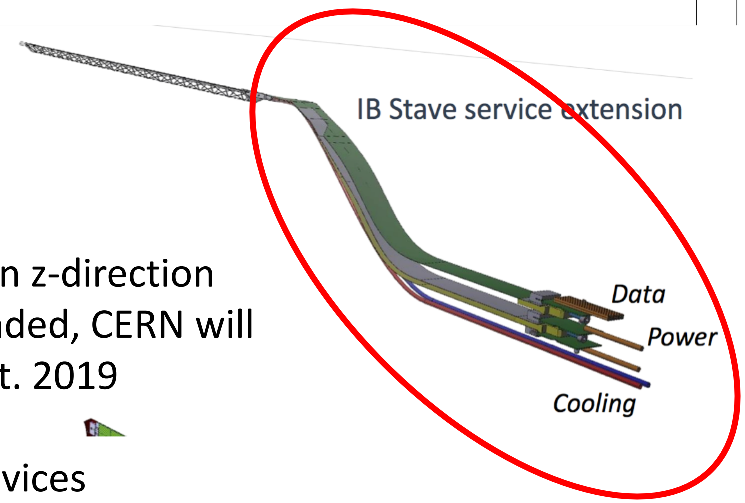
1) Extend cables to move the conical structure further out in z-direction;
2) Design/optimize INTT layers to fit current MVTX geometry;
   - FPC data cable can't be easily extended (max additional ~10cm, machine limit)
   - Reduce angle of cone – redesign C-structures and connectors

INTT-MVTX Conflict

Walt's talk

INTT 4-layers



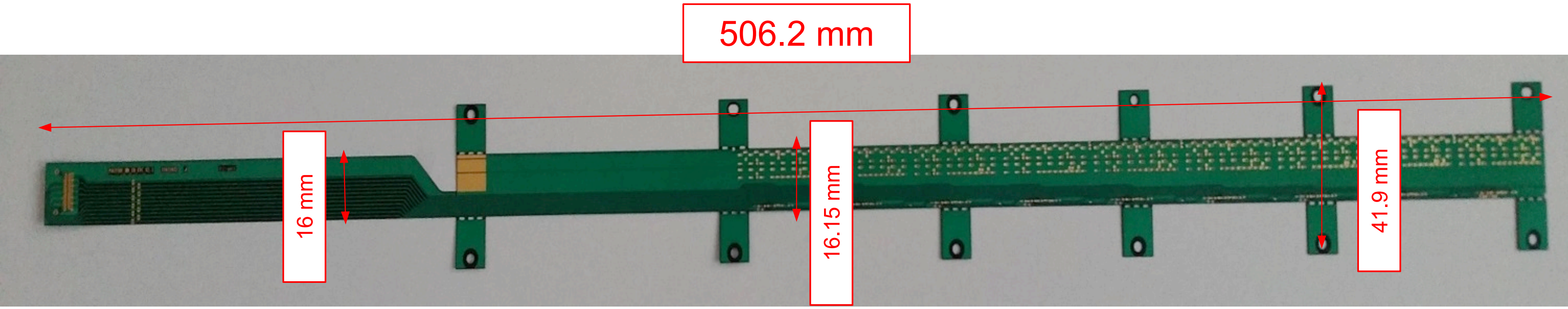


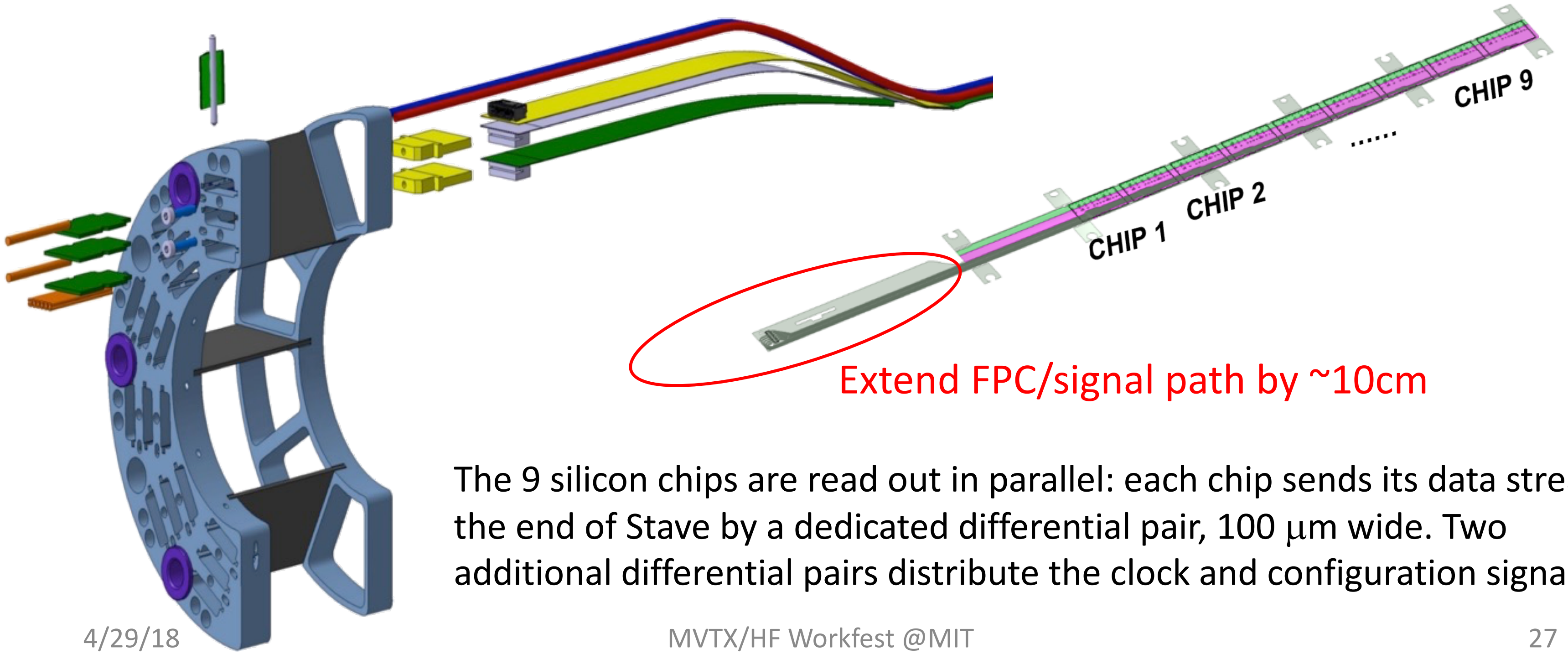
Extend cables to move the conical structure further out in z-direction

- FPC data cable is the HDI and can't be easily extended, CERN will produce extended 60cm long FPC prototype, ~Sept. 2019
- Make long power extension ~50cm,
- Reduce angle of cone to free up space for INTT services
- Redesign patch panel/cable connection shape and location

MVTX Flexible Printed Circuit (FPC)

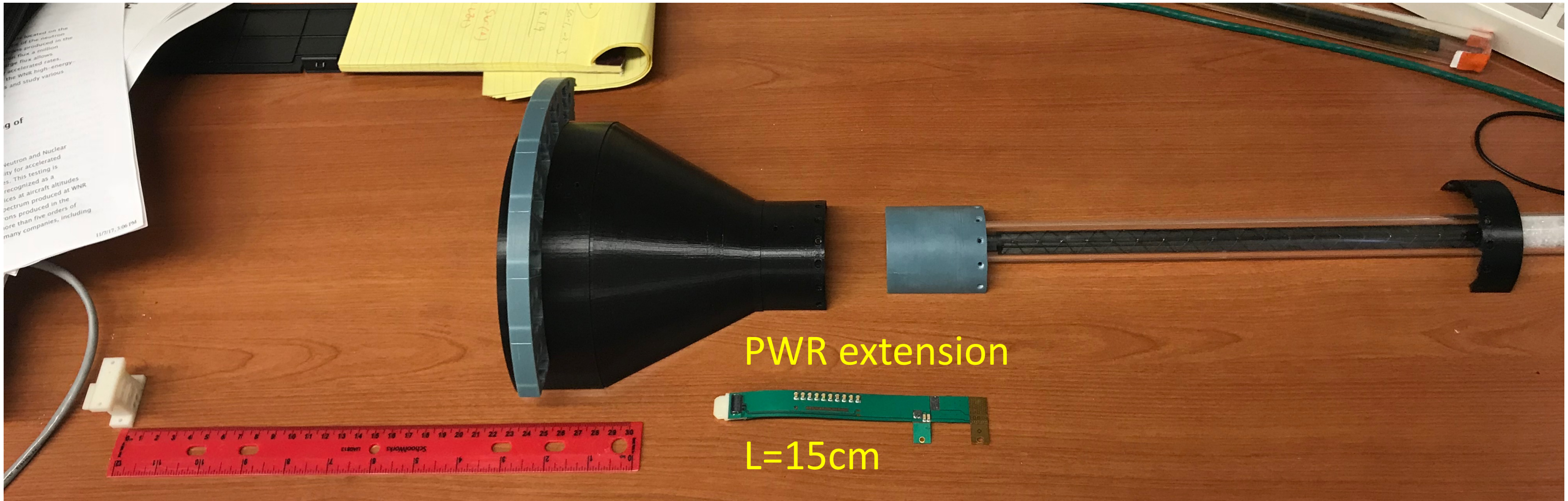
Extend MVTX Service Cables?
Maximum ~60cm for HS signal, TBD through R&D

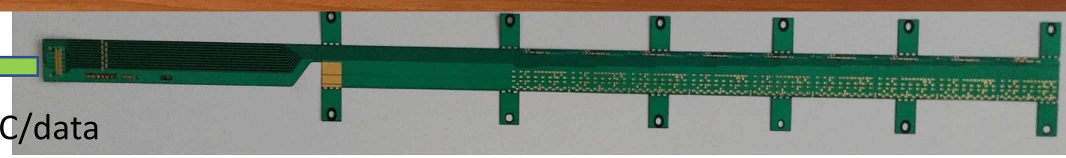




The 9 silicon chips are read out in parallel: each chip sends its data stream to the end of Stave by a dedicated differential pair, 100 μm wide. Two additional differential pairs distribute the clock and configuration signals.

MVTX Mockup & FPC Extension R&D

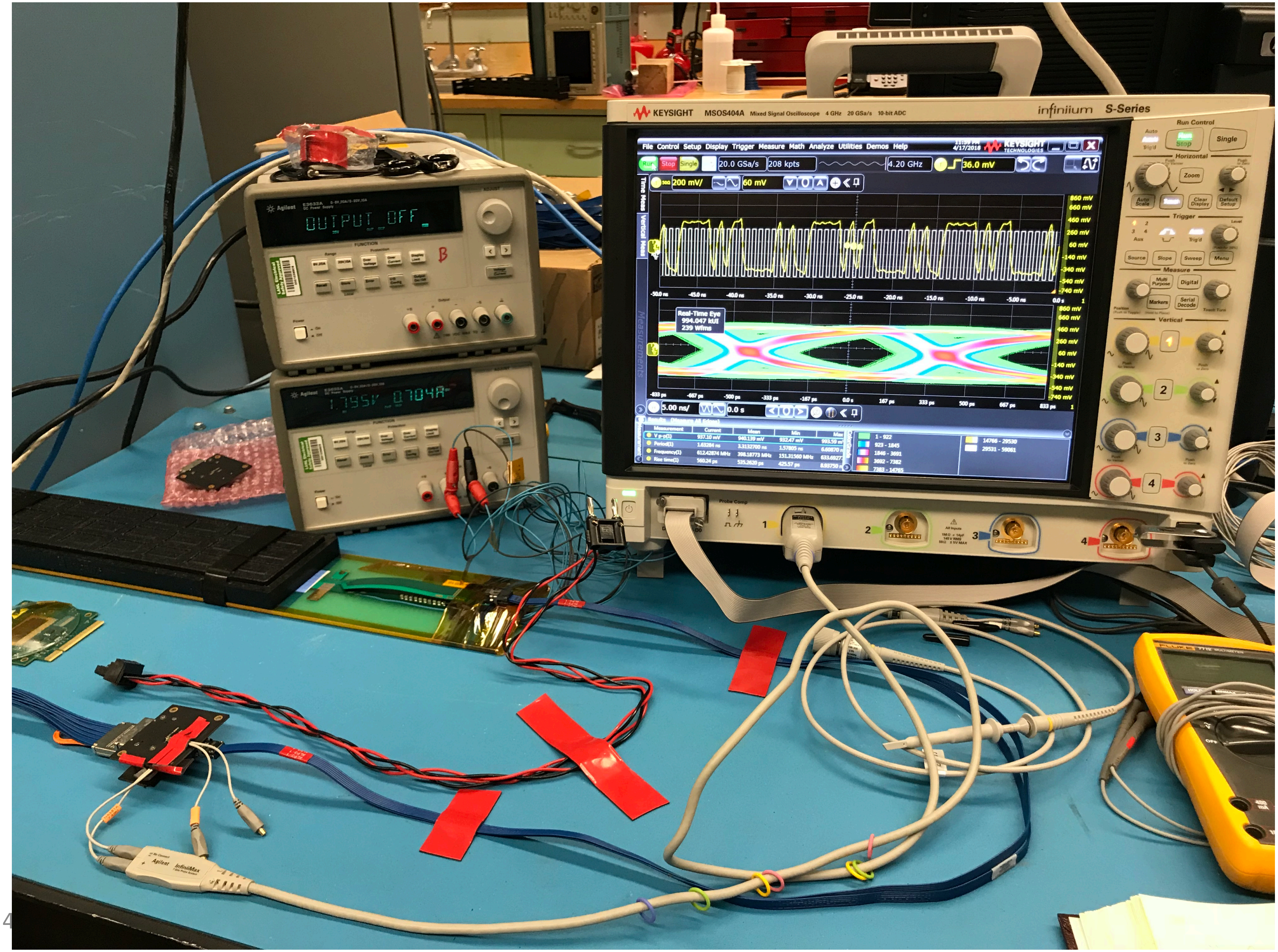




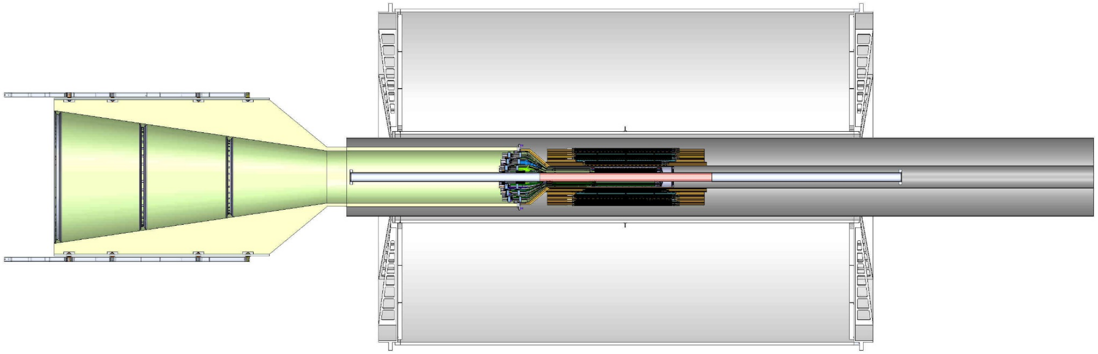
Extend FPC/data cable by ~10cm?, R&D

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.

SamTec Cable and FPC Extension R&D



To Do List



- FPC extension
  - Signal path, +10cm
  - Power extension, ~50cm

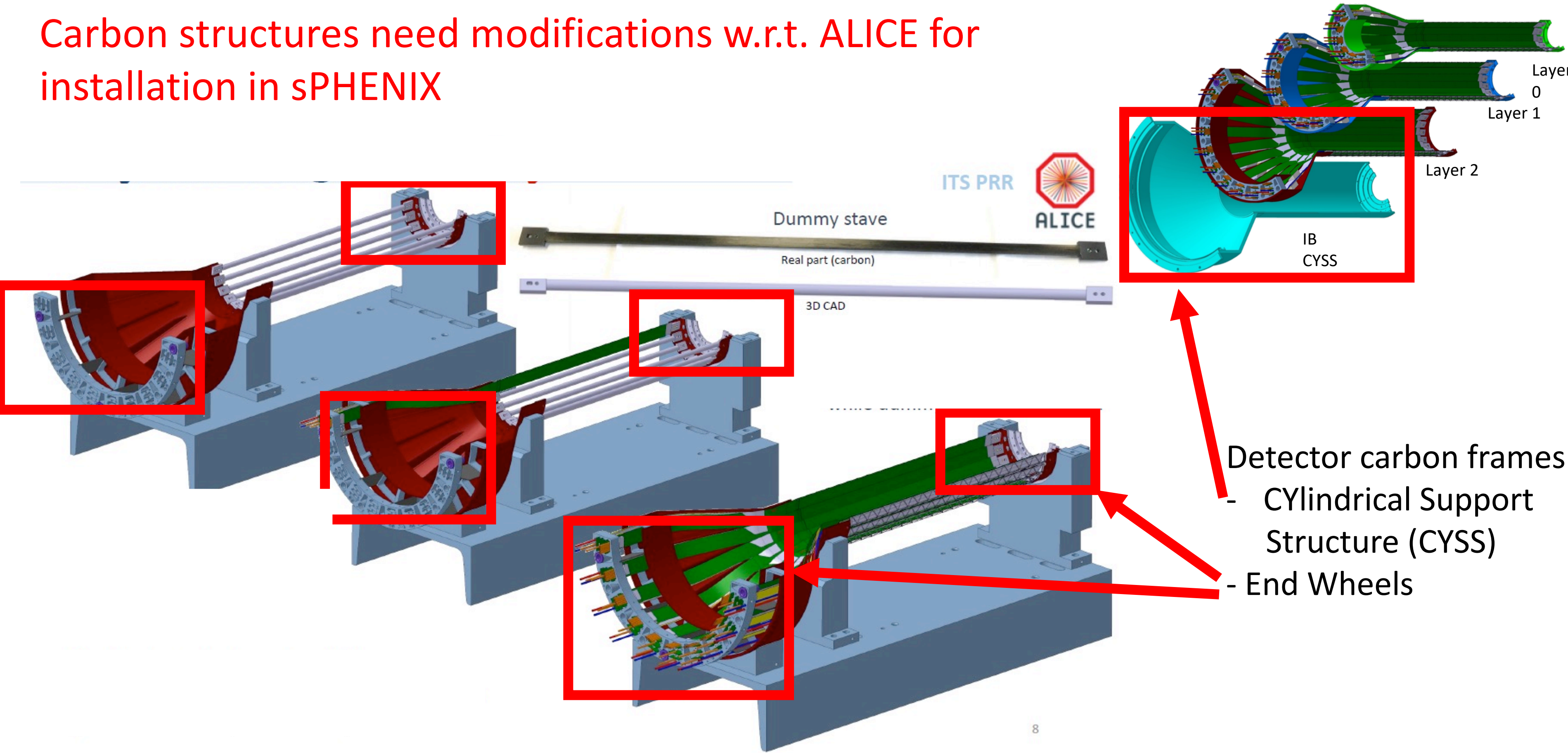
- SamTec cable length vs signal quality
  - 5~7m
  - RU location, MVTX electrical system integration
  -

- Carbon structure and connector design
  - FPC HS signal connectors
  - FPC power extension connectors
  - MVT Service barrel and mechanical system integration
  - Installation procedure

Carbon Structures

MVTX Carbon Structures

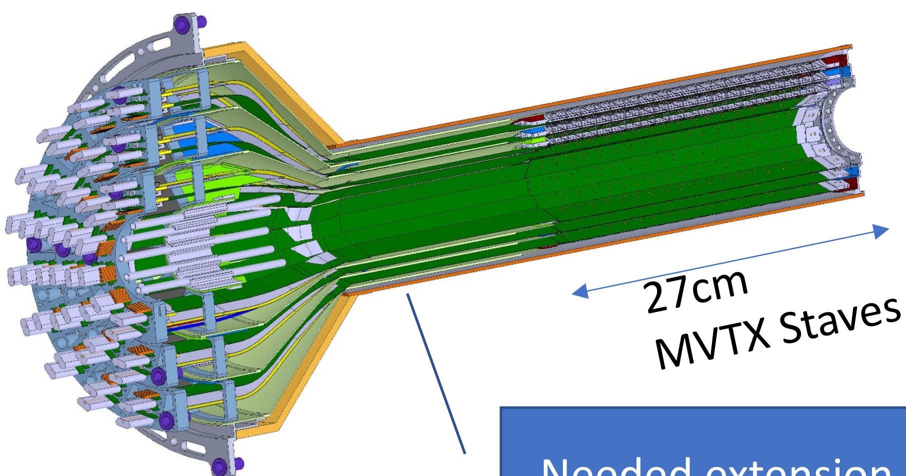
Carbon structures need modifications w.r.t. ALICE for installation in sPHENIX



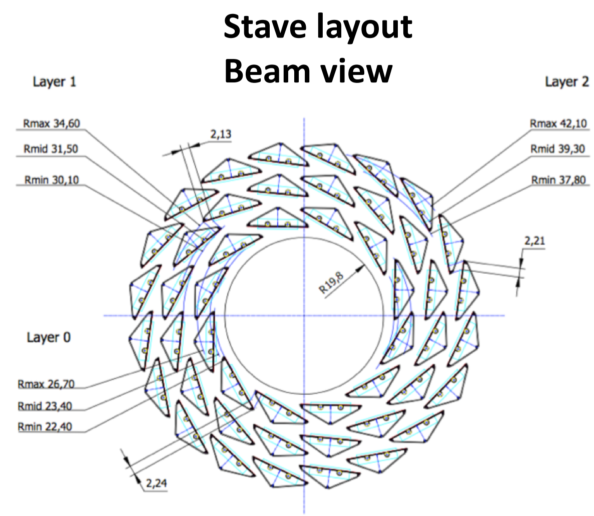
Detector carbon frames:
- CYlindrical Support Structure (CYSS)
- End Wheels

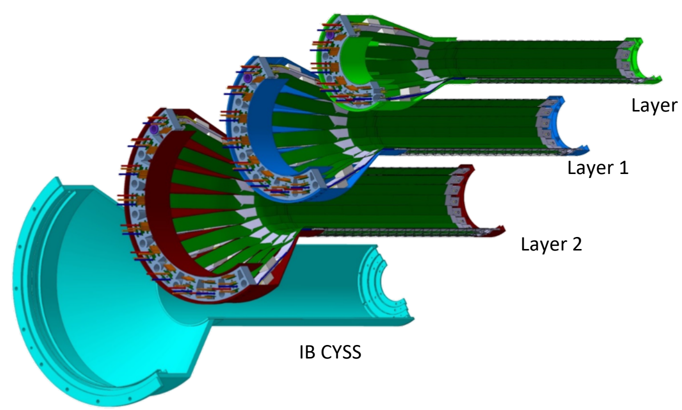
MVTX Mechanical Conceptual Design

- View of MVTX half detector assembly with extended central barrel

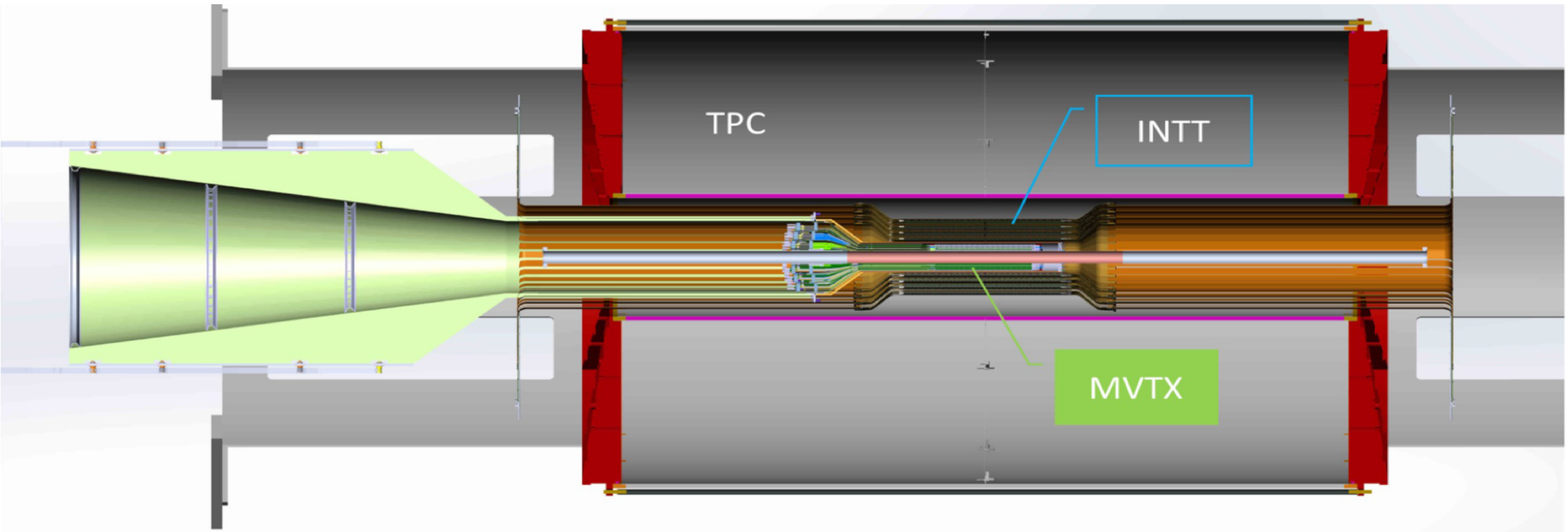


Needed extension for sPHENIX INTT integration

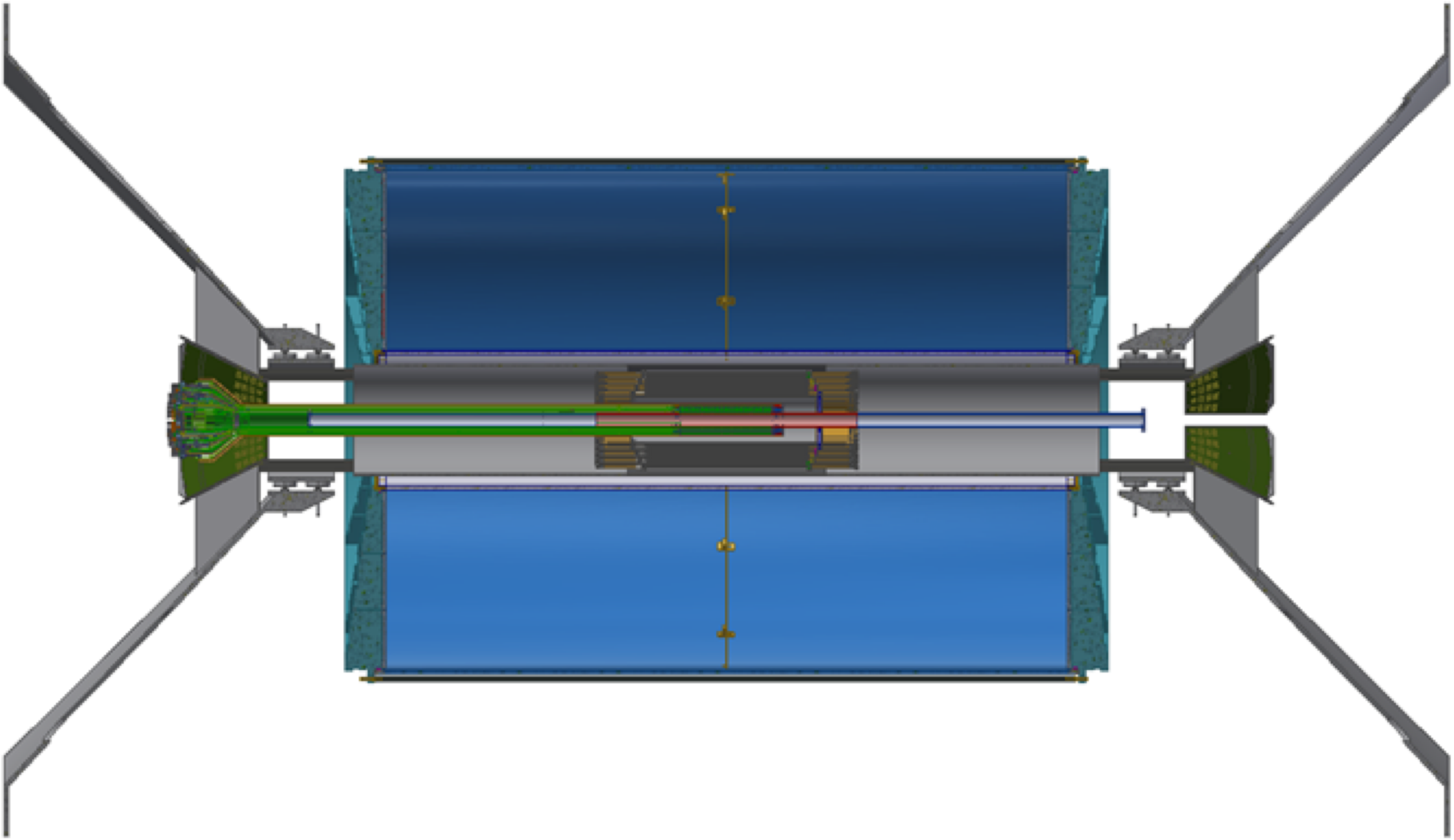




sPHENIX Integration: MVTX + INTT + TPC



Another one: MVTX + INTT + TPC from Dan Cacace, 4/27/2018



Cost & Schedule

Dave's talk

Updated Major Cost Items

Potential saving:
~$500K

WBS	Task Name	Cost (K)	Cost with Contingency+ Passthru (K)
1.5.3.1.1	Produce 84 staves	$966	$1.2M $1337
1.5.2.2	Readout Units(RDO)	$480	$250K $664
1.5.5.3.2.3.2	CYSS Cylindical Structure	$319	$424
1.5.5.3.2.3.3	COSS Conical Half Shell	$329	$438
1.5.4.3	Safety Systems	$139	$191
1.5.4.4	Stave Support+ Global Interface	$308	$465

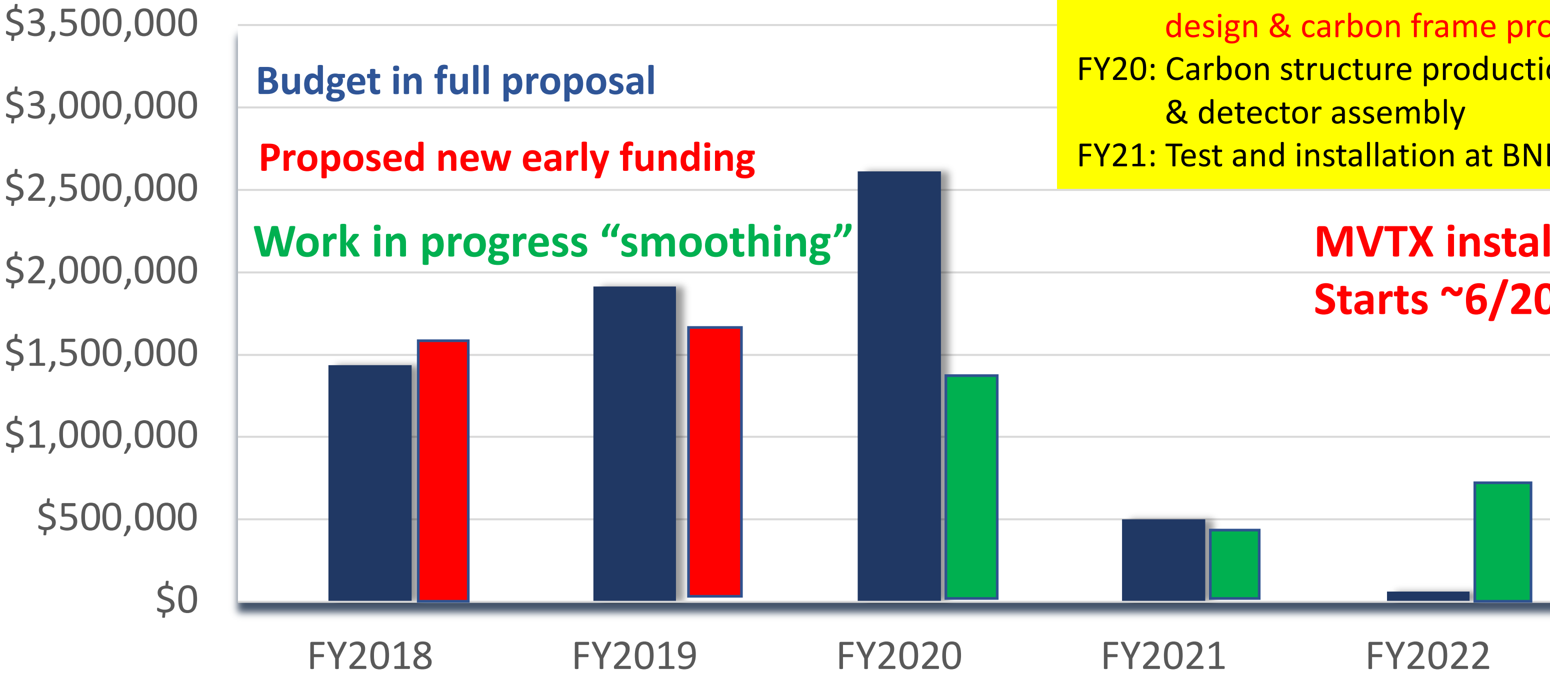
Table 6: Major Cost Items

1 CHF = 1.01 US $, 4/29/2018

Dave's talk

sPHENIX MVTX Cost & Schedule Profile

FY18: Stave + RU production
FY19: Stave/RU QA & test; mechanical design & carbon frame production
FY20: Carbon structure production & detector assembly
FY21: Test and installation at BNL



MVTX installation: Starts ~6/2022

	FY2018	FY2019	FY2020	FY2021	FY2022
MVTX Cost	$1,436,825	$1,911,749	$2,610,068	$501,407	$63,152
New numbers:	**$1.52M**	**$1.6M**			

RU units moved from FY19 to FY18

*** 50% cost reduction due to joint production with ALICE**

FY20-22: funding profile smoothing

Nice work by Dave, Maria + others

Possible Contributions from China?

Timeline

Now

2018

2019

2020

2022

- Offline detector and physics simulation
  - sPHENIX
  - EIC

(MVTX & Heavy Flavor Topical Groups)

- FPC extension R&D at CERN, LANL
  - MVTX+INTT+TPC integration
- Electronics production test and QA
  - Readout Units/CERN, FELIX/BNL
  - Power boards and control system
- Stave assembly, test and QA
  - CERN, China, US
- Slow control firmware/software development
  - Online monitoring
  - Safety controls
- Carbon structure design and/or fabrication?
- Detector assembly and test
  - LBNL, half-barrel assembly, test, QA
  - Final assembly & installation at BNL

RU Production Plan

Plan-A

- To be part of ALICE ITS production
- Timeline:
  - Production starts ~May 2018, available by ~end of 2018, fully tested
- Need to make commitment "NOW"
  - BNL management actively working on funding RU through RHIC $

Plan-B

- Produce RU later, ~2019 as funding allows?
  - Procure GBT chips from CERN
  - Production & test in US, UT-Austin, LANL et al.
- Higher cost, 2x
- Higher technical and schedule risks

Stave Production Plan

Plan-A

- Produce staves following the completion of ALICE IB at CERN, using ALICE facility
- Timeline:
  - Starting as early as Aug/Sep 2018 +, last about 6 months for production and test
- All 84 staves produced and tested at CERN
- BNL management actively working with DOE to build staves at CERN

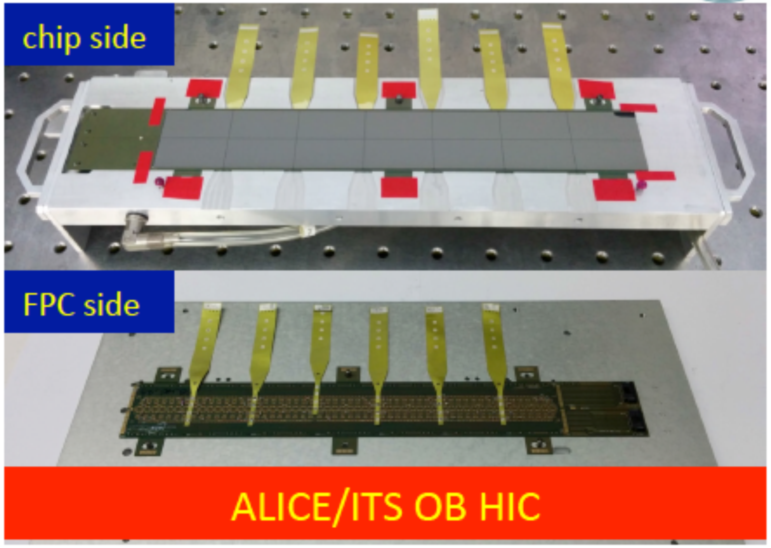
Plan –B

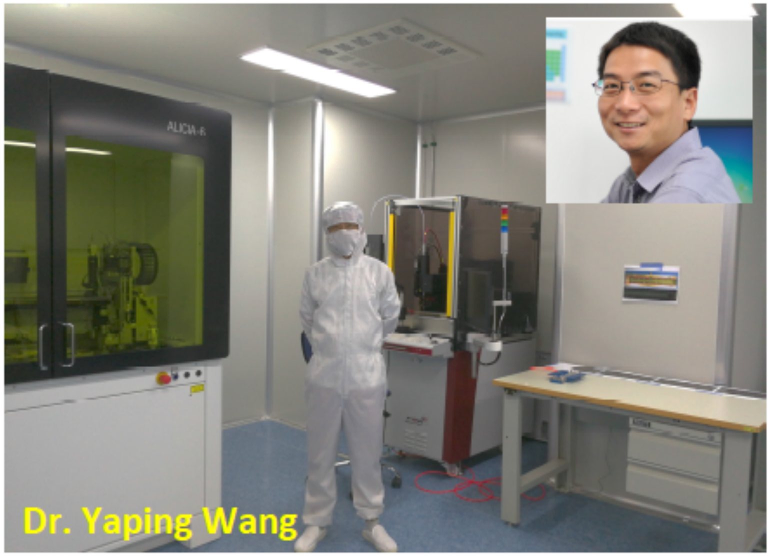
- Produce full staves at CCNU later as funding allows, ~2019?
- Earliest starting date - May 2019 + , ~12 months (could be shorter)
- Higher technical and schedule risks
- Impact on cost, TBD

Following Slides from Yaping Wang/CCNU, 1st sPHENIX workshop in China

Effort & Plan on MVTX – Feasibility

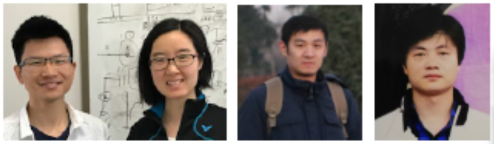
- Efforts on ALPIDE chip design since 2012
- Machine workshop (~150 m^2)
- Clean room was constructed and run in good status since November, 2016
  - ✓ Ground floor (vibration velocity RMS ~ 3 μm/s)
  - ✓ Temperature/humidity controllable
  - ✓ ISO6 clean level ~ 70 m^2 (2.6 m head room) + ISO7 clean level ~ 20 m^2 (2.9 m head room)
  - ✓ Grounding terminals provided (ESD protection)
  - ✓ Gas supply system
- Pixel chip assembly & inspection machine (IBS ALICIA-6), wire-bonding machine (F&K Delvotec G5 64000), pull tester (DAGE 4000) and HIC testing system are in working status
- 20% ALICE/ITS OB HIC module assembly & test (~7500 ALPIDE chips) for one year
- Pre-series production started in Dec. 2017
- Series production started in April, 2018
- Long-term plan: (1) ALICE ITS calibration and alignment; (2) open-bottom production at LHC.

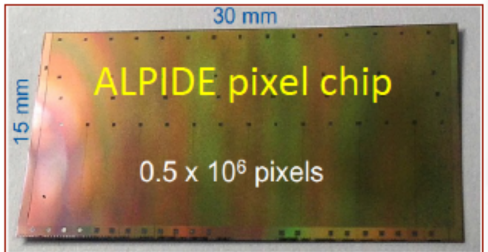




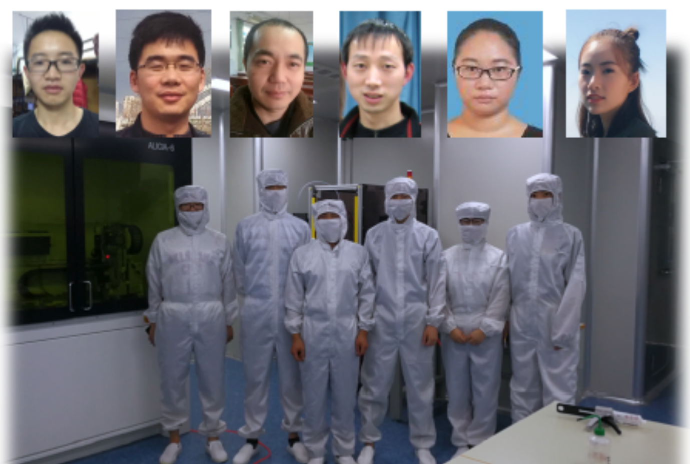
Effort & Plan on MVTX – Feasibility

Expertise @CCNU

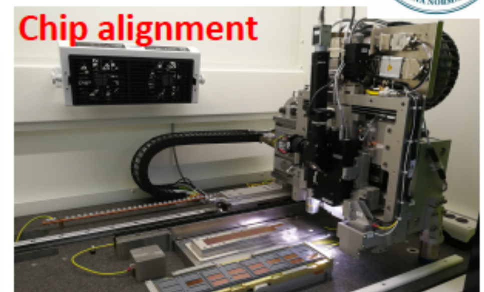




ALICE/ITS Chip Design/ Testing（CCNU）：
Chaosong, Ping, Mangmang, Shuguang

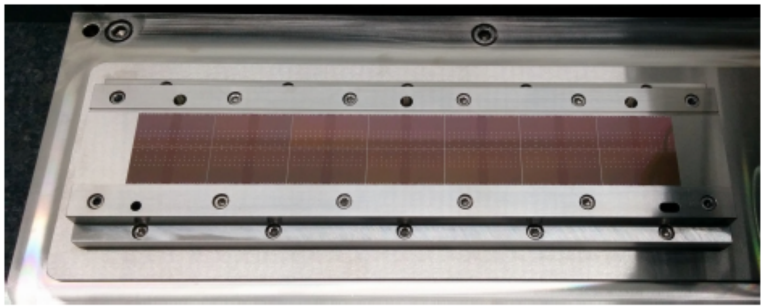


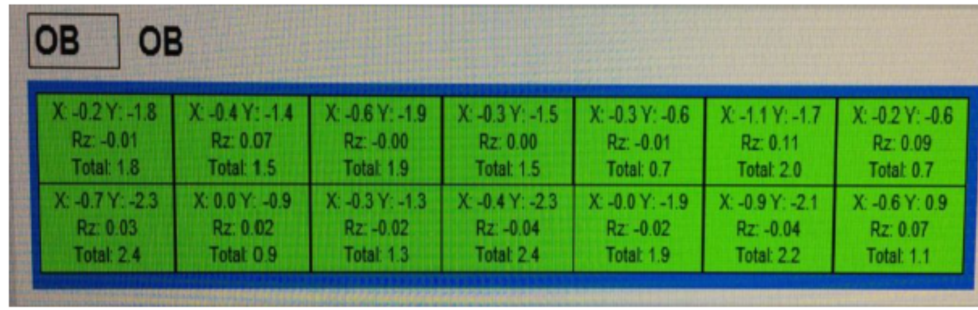
ALICE/ITS OB HIC Assembly Team（CCNU）：
Biao、Jun、Daming、Kai、Peipei、Wenjing



Effort & Plan on MVTX – Feasibility

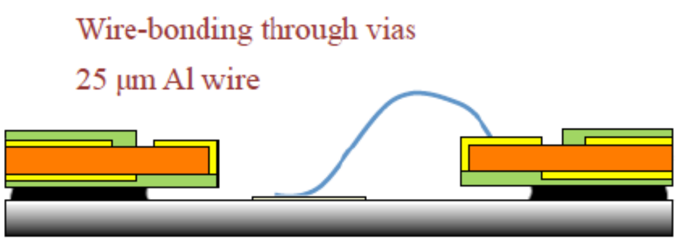
- ALPIDE chips (dimension of 3cmx1.5cmx100μm) can be automatically aligned with positioning accuracy of better than 5 μm@3σ by the ALICIA machine.

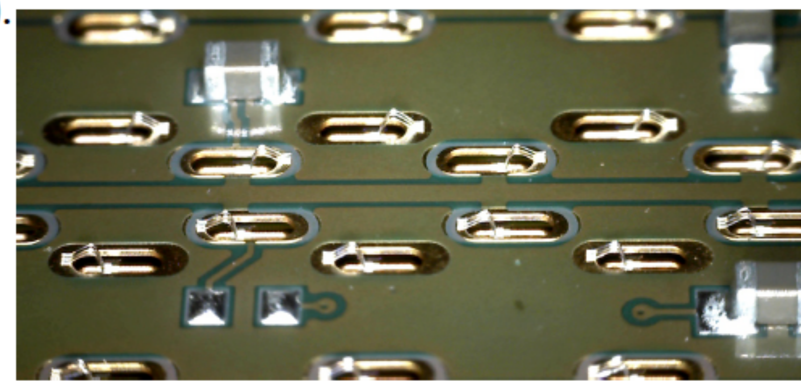




- The chip-FPC interconnections are realized with wire-bonding method, which is done fully automatically by the F&K G5 64000 machine with positioning accuracy ~ 5 μm@3σ (large working area).

FPC-to-ALPIDE interconnection





- R&D on chip-FPC interconnections technology, such as laser bonding.

Stave Production @CCNU

Effort & Plan on MVTX – Interests

- Physics interests on the sPHENIX/MVTX at RHIC
  - B-jets & B-hadrons
  - HF-jet correlations
  - …

- MVTX stave assembly and test
  - sPHENIX MVTX effort can be started after the ALICE ITS upgrade project (around May, 2019)
  - Facilities and technical resources of CCNU and other institutes are available for HIC production (replace assembly jigs + short-time training)
  - Infrastructures and tooling need to be constructed for stave assembly & test + technical training
  - Estimated production period: 1 year for 84 staves (~4 months for HIC assembly/test + ~8 months for stave assembly/test incl. training)

- MVTX detector and physics simulations

Effort & Plan on MVTX – Organization & Time Schedule

Participants from China side:

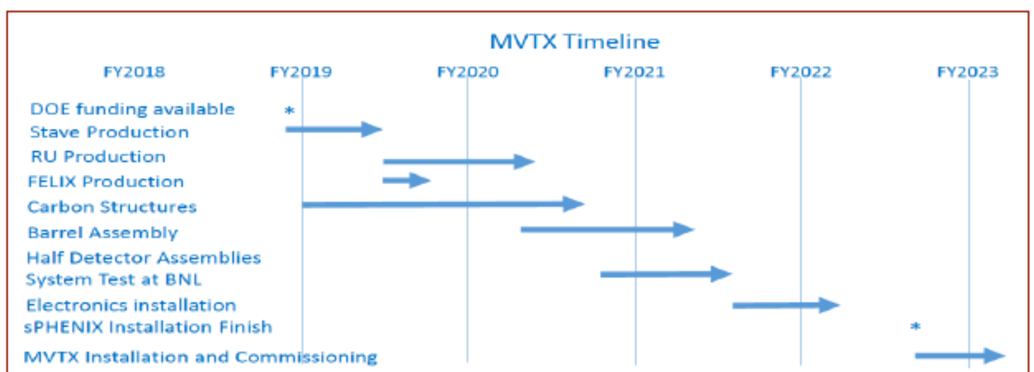
1) Central China Normal University (CCNU): stave assembly & test
2) Institute of Modern Physics (IMP/CAS): stave assembly & test (collaborated with CCNU)
3) University of Science and Technology of China (USTC): chip & stave test, simulations
4) Sun Yat-Sen University (SYSU): MVTX detector and physics simulations

Manpower:

New: Also IHEP silicon group possibility

- 2 FTE + few students from CCNU (additional postdoc in due time)
- 2 FTE + few students from IMP/CAS
- Other institutes?

Production can be started since May 2019 after ALICE ITS upgrade:



Carbon Structure Design and Fabrication

- Mechanical system design
  - MIT + LANL + LBNL + BNL
- Production
  - LBNL

- Alternative path for fabrication being explored
  - Europe (France & Italy, used for ITS Upgrade)
  - Asia (Korea, China)

Quote on “CYSS” from Korea

from Prof. Kwon/Yonsei Univ.

NO : YS18042701 고객에게 신뢰받는 기업

C - on
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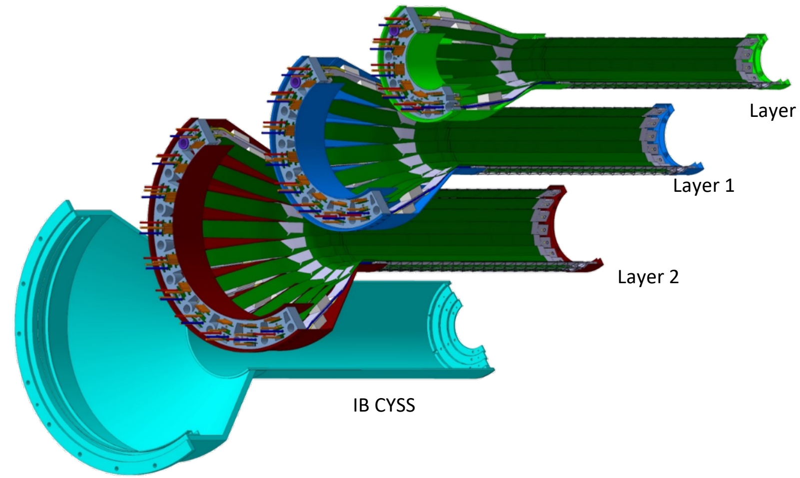
Cust	연세대학교	Terms	T/T
Cust Name	권 영 일 교수님	Payment	Advance 100%
Provider	Kim Hyun Chun	Delivery	5 weeks
C.C		Delivery Place	Korea
Date	27-Apr-18	Cancellation	90% for less than 1 weeks
Expired date	15 days		after Purchase Order received

QUOTATION

◎ Price List for Fabrication for ITS detector Upgrade parts

NO	DESCRIPTION	Q'TY	U/PRICE	AMOUNT
	* ITS Detector Upgrade	1 Set		$ 3,000
1	IB-CYSS Flange	1		
	- Matrial - AL (Treatment : Hard Anodizing (Black)			
	Need to reconfirm matrial (AW-7075)			
	Normally we are using AL 6061			
2	IB-CYSS Cone	1		
	- Matrial - Carbon Fiber			
3	IB-CYSS Cylinder	1		
	- Matrial - Carbon Fiber			
4	IB-CYSS Flange C Side	1		
	- Matrial - AL (Treatment : Hard Anodizing (Black)			
	Need to reconfirm matrial (AW-6082)			
	Normally we are using AL 6061			
	Total Amount			$ 3,000



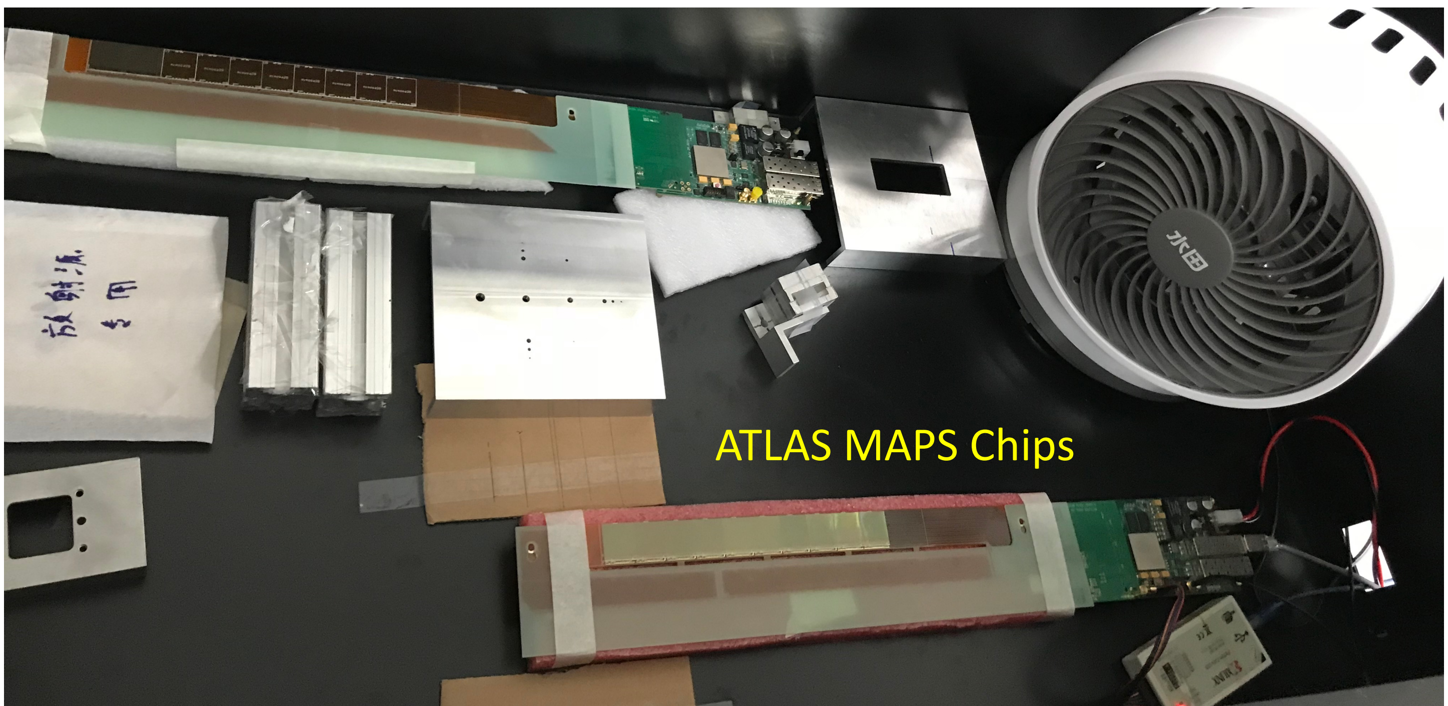
Based on **ALICE CYSS** design AutoCAD:
~$3K, 5 weeks delivery

- One of two IB CYSS shell only
- Will follow up on this development, also for the end-wheels/conical shells

MVTX Project:
CYSS: $424K (included review/design: $40K)
($103K_Material + 216K_Labor + 37%)

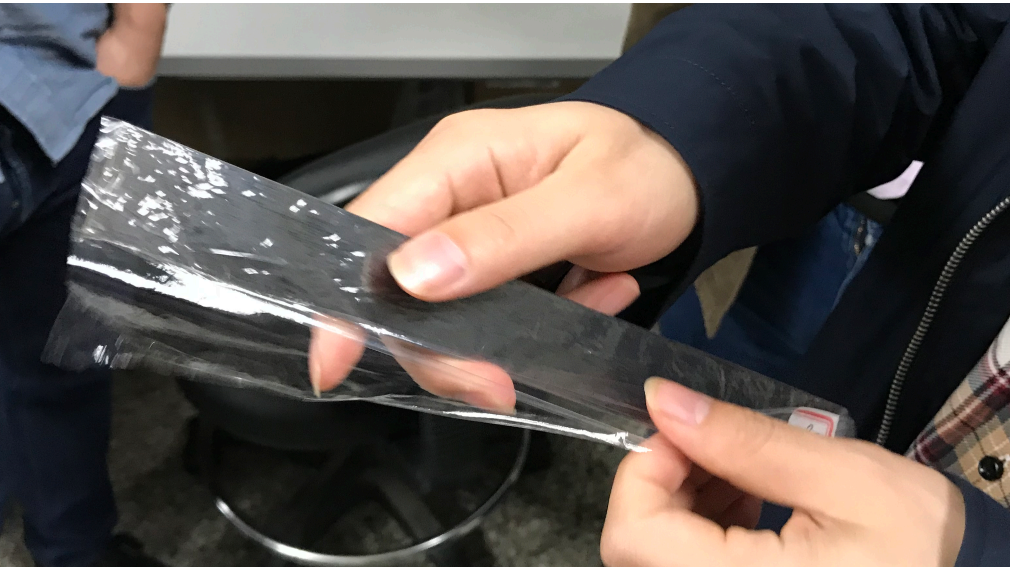
Institute of High Energy Physics in China (IHEP) - Silicon Group

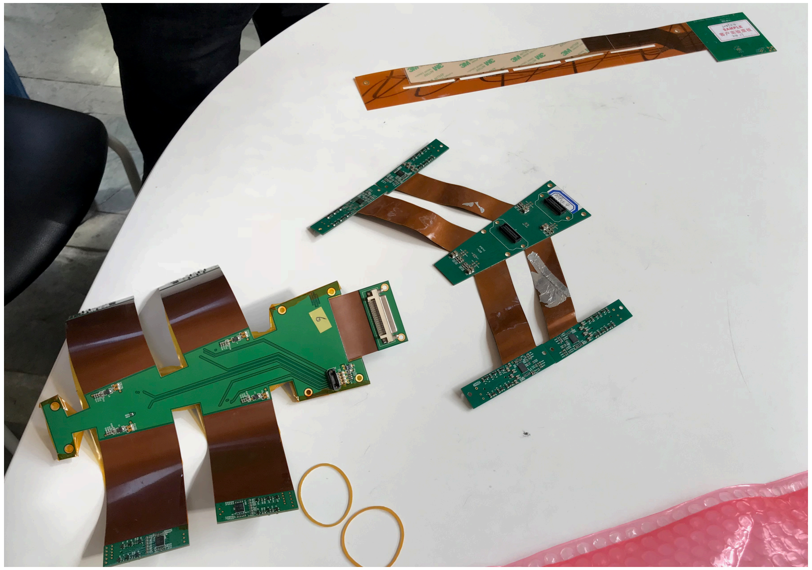
- IHEP is working on ATLAS MAPS detector R&D
  - Carbon structure
  - Sensor and readout
  - Very interested in sPHENIX MVTX project



Encouraged IHEP Silicon Group to join sPHENIX!

- Carbon structure R&D
  - A local institution, material science, in Hangzhou
- FPC R&D
  - A local company, can make up to ~100cm long "Copper FPC", "Al" not clear





Summary and Outlook

- MVTX full proposal completed
  - Expanded science
  - sPHENIX baseline

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

- Cost and schedule update in progress
  - Major item cost and production plan
  - Funding profile smoothing
- Excellent progress in R&D
  - Readout and controls proof-of-principle demonstrated
  - Conceptual mechanical system design being developed
  - Possible new collaboration on carbon and FPC work
- MVTX+INTT+TPC integration in progress
  - Electrical and mechanical system
  - sPHENIX wide coordination through Office of Integration
    - Mini sPHENIX integration review in ~June 2018?
- To be ready for sPHENIX Day-1 Physics in 2023
  - sPHENIX and later EIC possibility

Backup slides

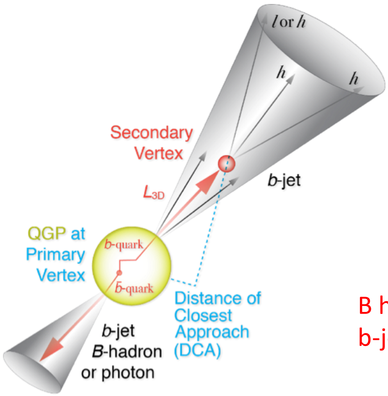
Physics

RHIC Multi-Year Plan: sPHENIX 2023-2027+

Evolving

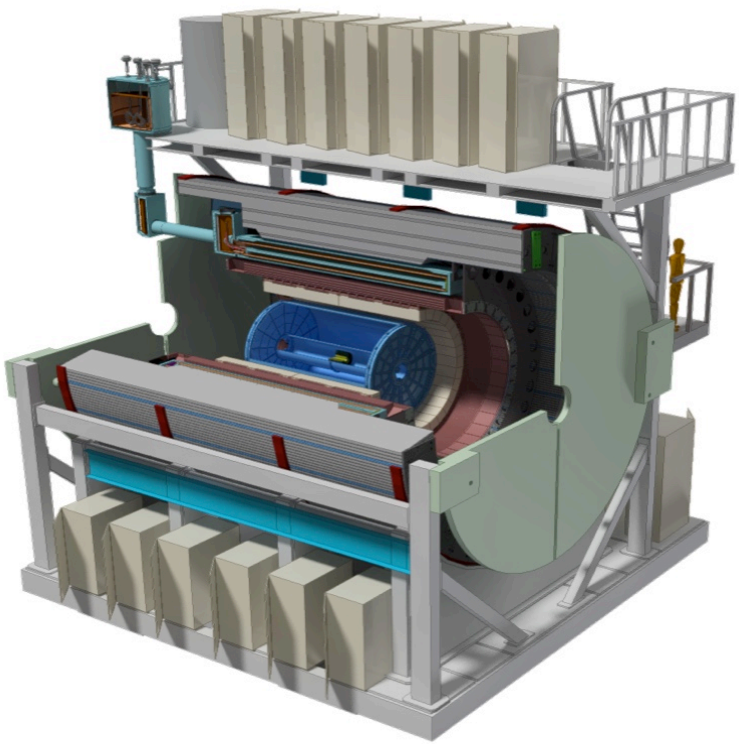
Year	Species	Energy [GeV]	Phys. Wks	Rec. Lum.	Samp. Lum.	Samp. Lum. All-Z
Year-1	Au+Au	200	16.0	7 nb^{-1}	8.7 nb^{-1}	34 nb^{-1}
Year-2	p+p	200	11.5	—	48 pb^{-1}	267 pb^{-1}
Year-2	p+Au	200	11.5	—	0.33 pb^{-1}	1.46 pb^{-1}
Year-3	Au+Au	200	23.5	14 nb^{-1}	26 nb^{-1}	88 nb^{-1}
Year-4	p+p	200	23.5	—	149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

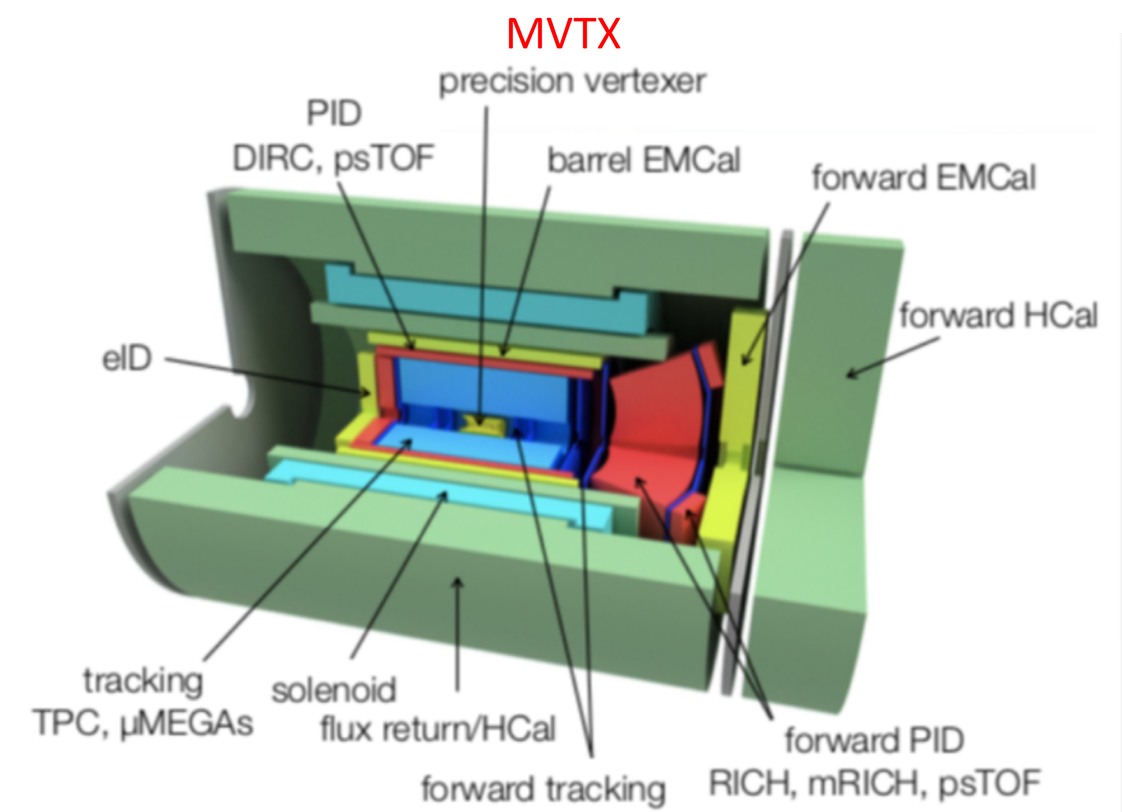
- Precision B-tagging w/ MVTX:
  - Tracking resolution better than 50um @pT=1GeV
  - High multiplicity HI collisions
  - Low multiplicity but high rate p+p collisions
  - High efficiency and high purity



B hadrons/pT<15GeV: *O*(1M)
b-jets/pT>15GeV: *O*(100K)

Physics & Simulations: from sPHENIX to EIC

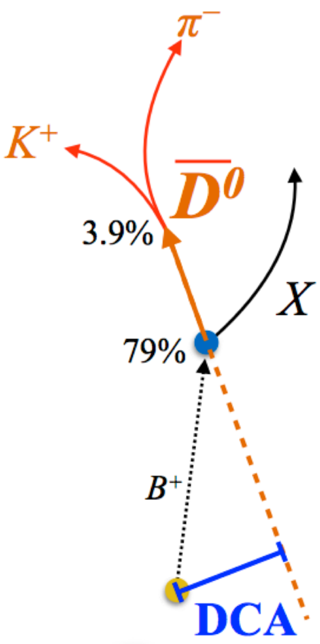


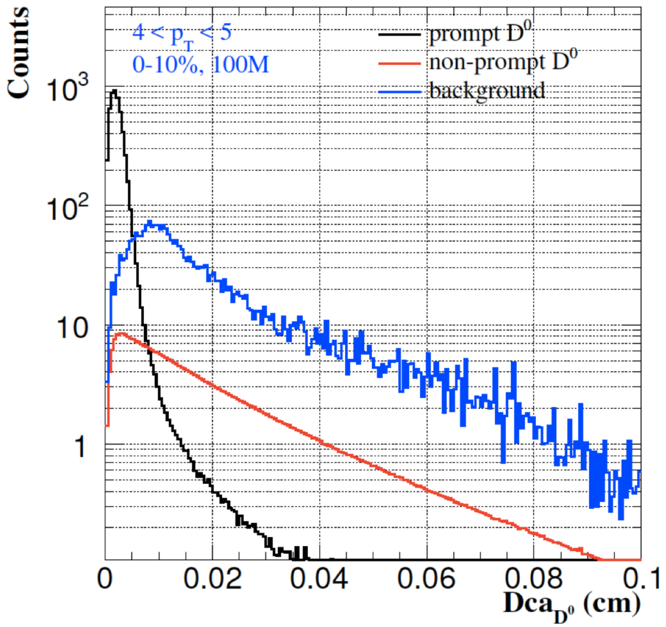


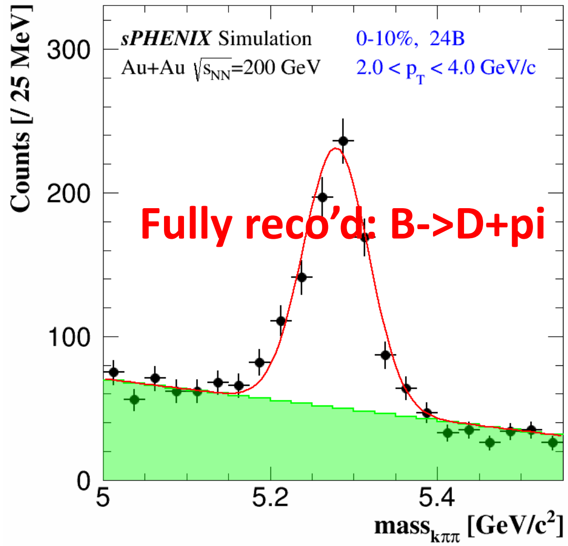
B-hadron Tagging

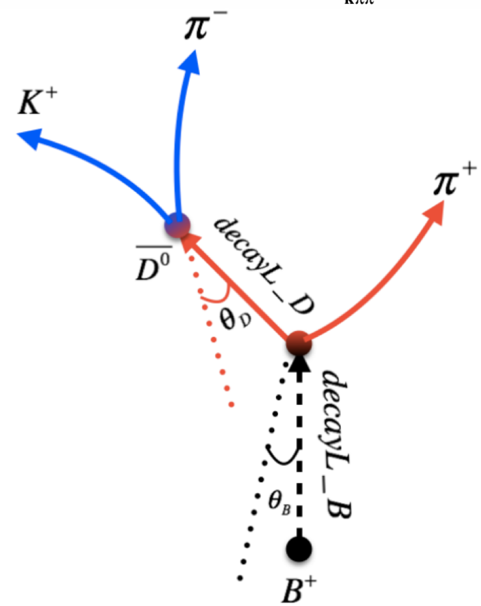
- Impact parameter (DCA) method to tag non-prompt D^0 from *B*-meson decays
- Inclusive and exclusive channels possible

Partial reconstruction: B->D+x





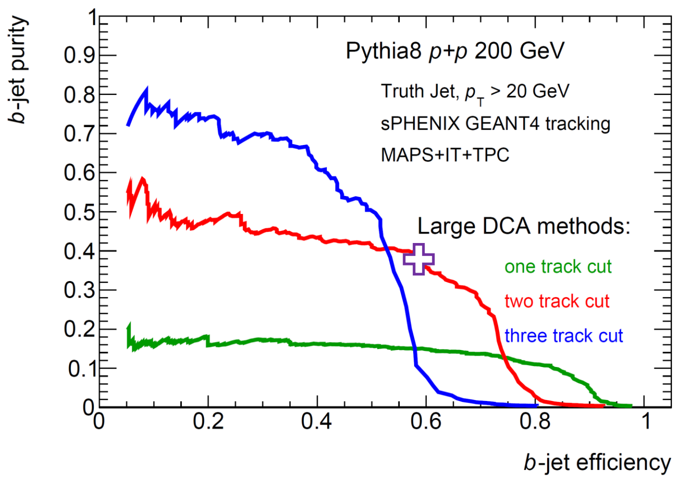


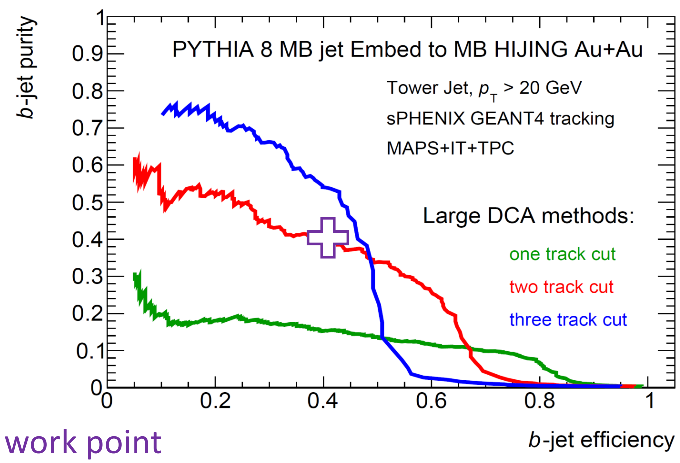


b-jet Tagging in *p*+*p* and Au+Au

- Fully implemented MVTX models used in performance projection
- *b*-jet tagging projection evaluated with full tracking + calorimetry simulation
  - Tagging work point has been stable (60% Purity 40% eff for pp)
  - Central Au+Au Tagging work point has been stable (40% Purity 40% eff)

- Performance has been stable using truth jet finding or calorimetry reconstructed jet finding

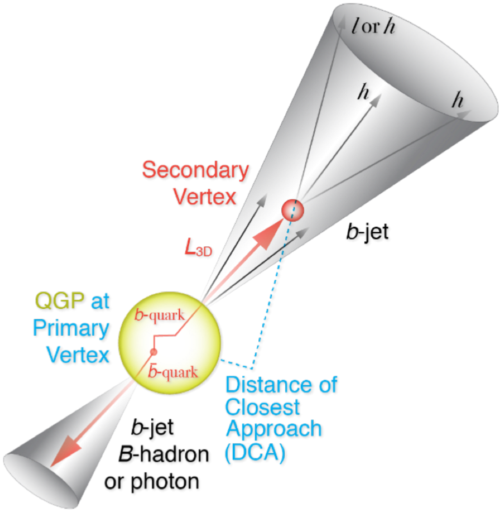


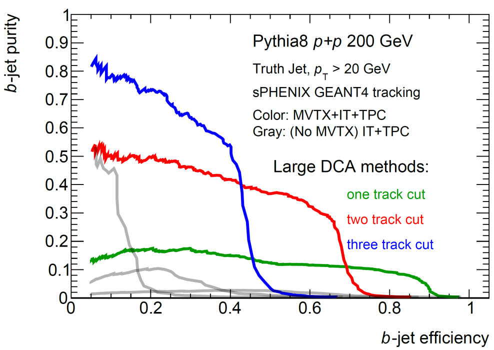


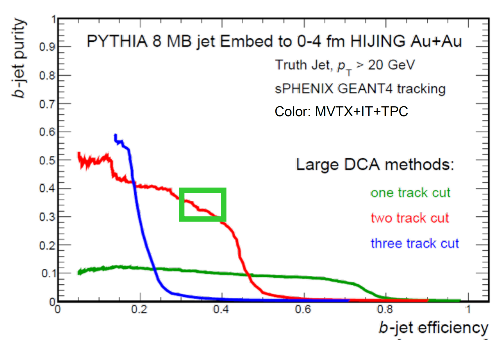
✚ sPHENIX b-jet work point

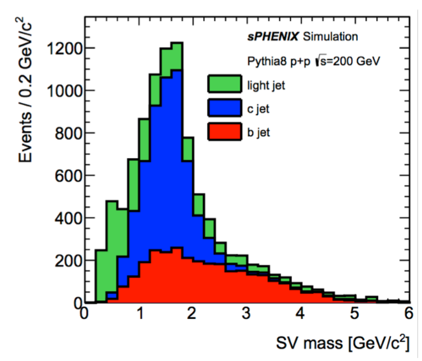
B-jet tagging

- Multi-tracks w/ large DCA
- 2^{nd} vertex mass reco'd







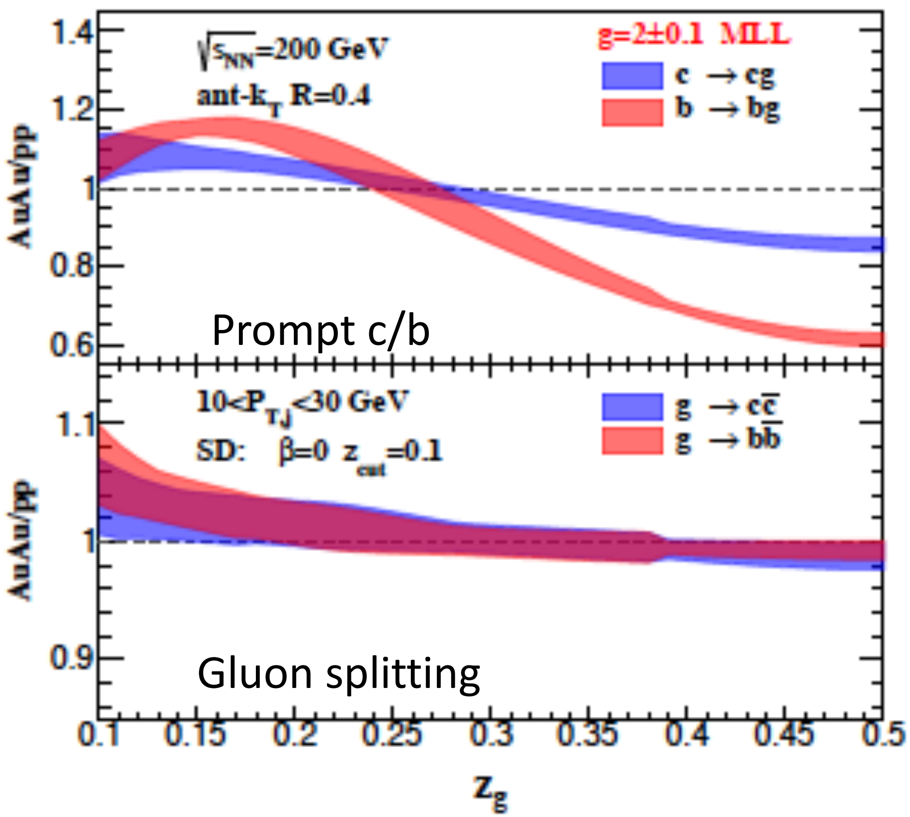


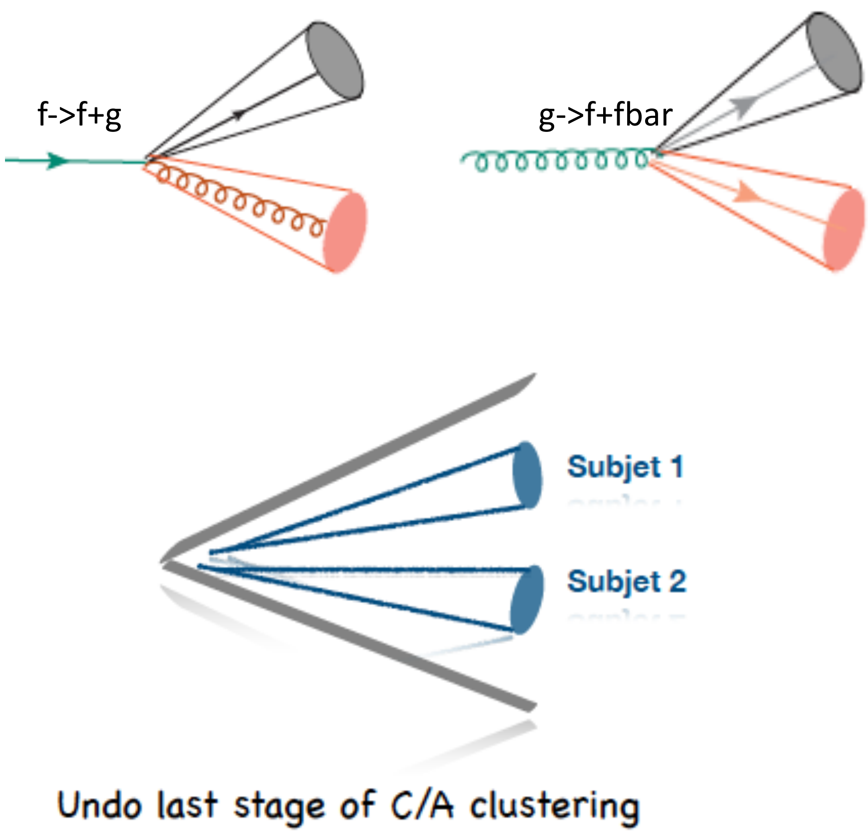
CMS work-point, Phys. Rev. Lett. 113, 132301 (2014)

New Insight into QGP: HF-Jet Substructure

QCD Splitting function in QGP

H. Li & I. Vitev (2018)

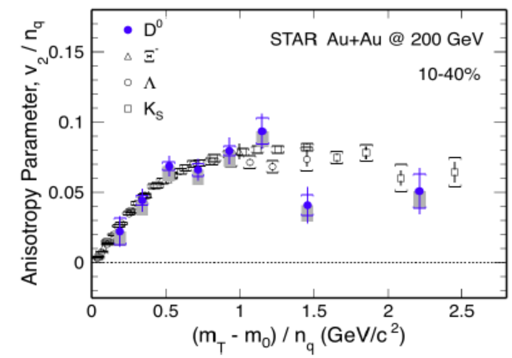




Define $$z_g = \frac{\min(p_{T1}, p_{T2})}{p_{T1} + p_{T2}}$$

New Insight into QGP: B v2

D-meson: v_2 scaling observed at RHIC



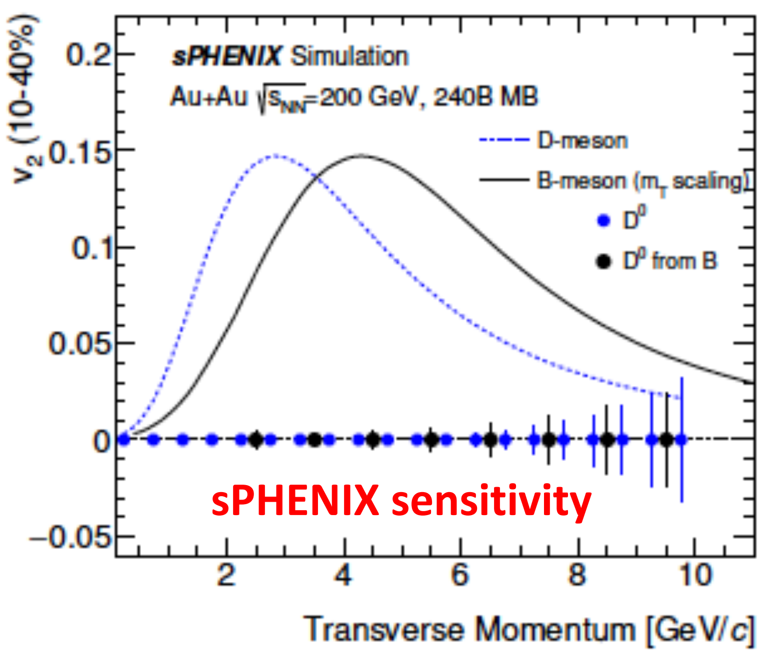
STAR, PRL 118 (2017) 212301

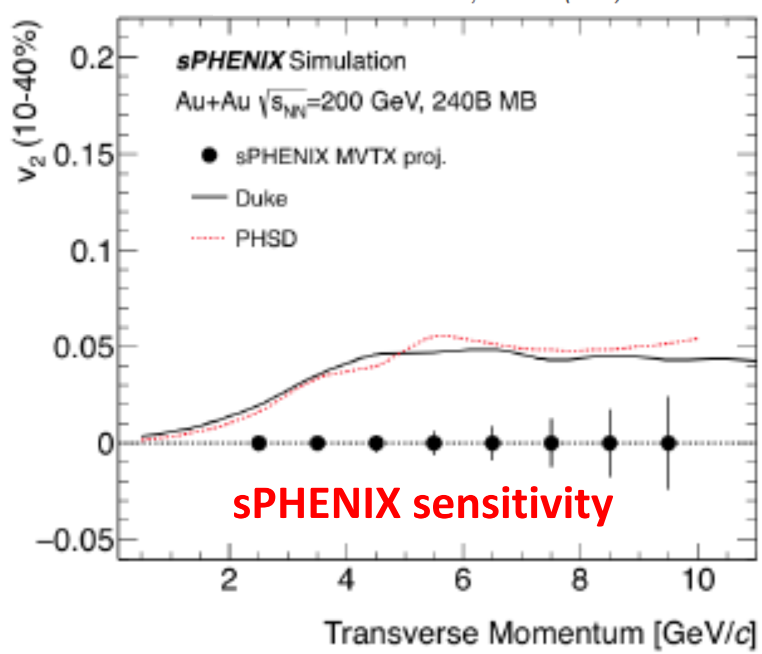
Very active theoretical investigation:

- LANL model
- CUJET
- Duke model
- TAMU
- UrQMD
- AMPT
- PHSD
- Ads/CFT
- BAMPS
- HQ+EPOS2
- JetScape
- ....

Various new model calculations, PHSD, AMPT etc, for B-hadron v2:

- Significant non-zero v2 suggested, but may NOT follow the scaling due to large b-mass!

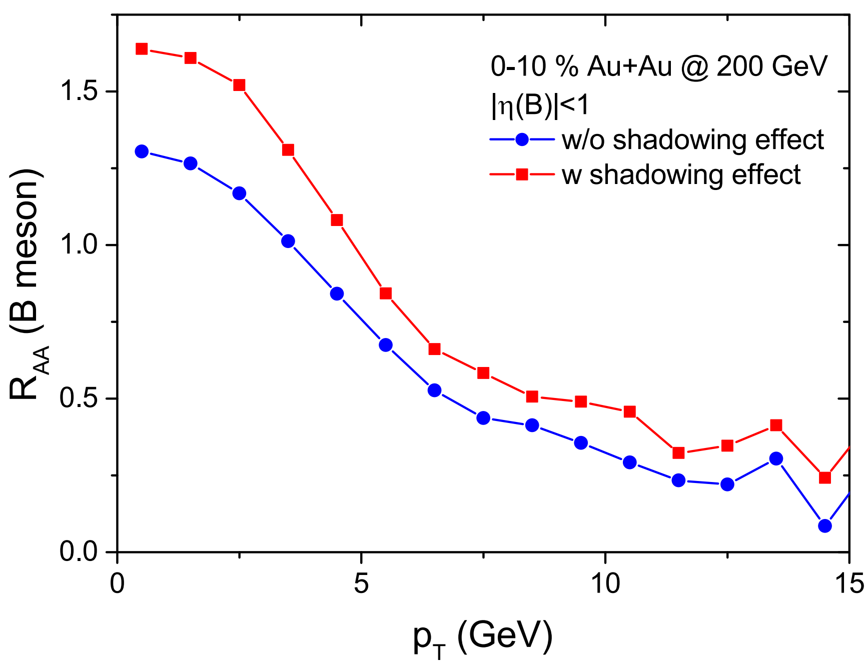


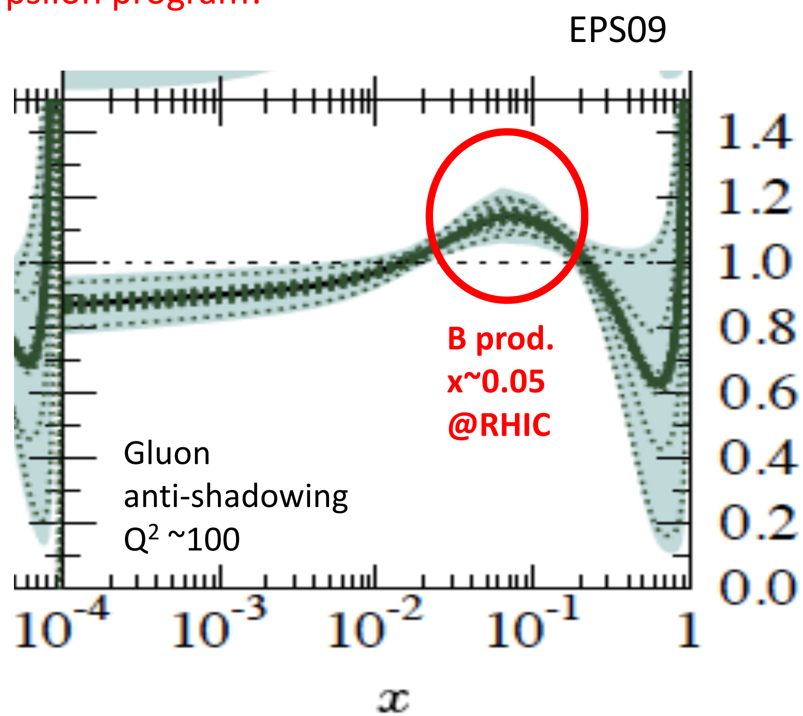


e Theoretical Inputs (II): B-meson R_AA

New calculations from PHSD for B-hadrons:

- Potential significant anti-shadowing effects
- Open b-bar in AuAu, very important baseline for Upsilon program!

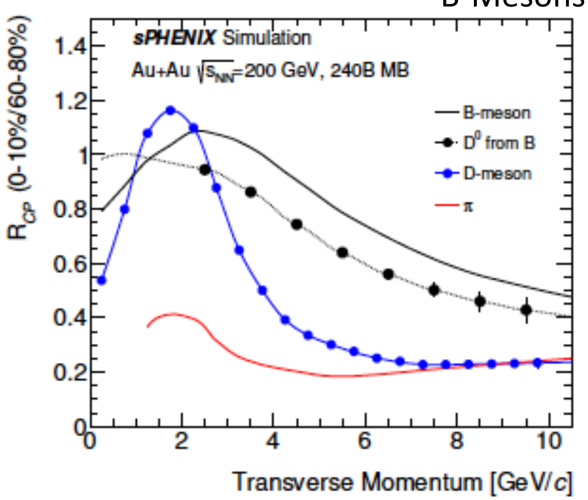


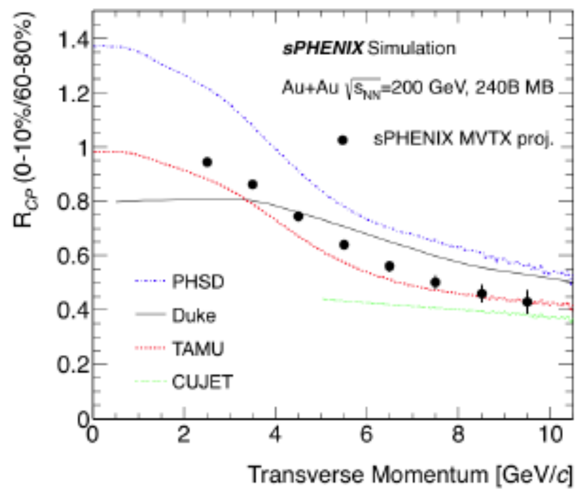


sPHENIX Projected R_{AA} Sensitivity

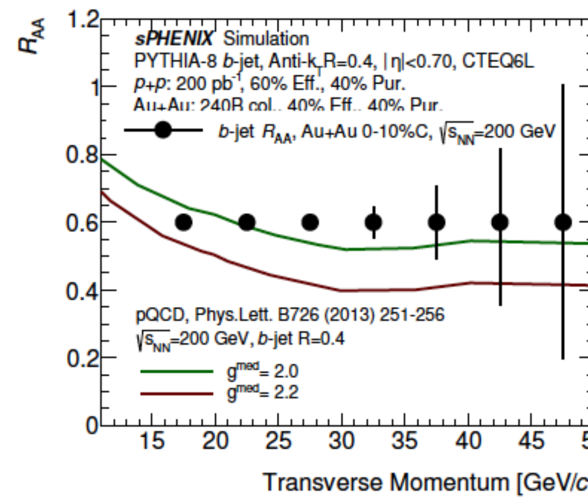
Open questions to be answered: energy loss mechanisms and QGP medium properties

B-Mesons





B-jets

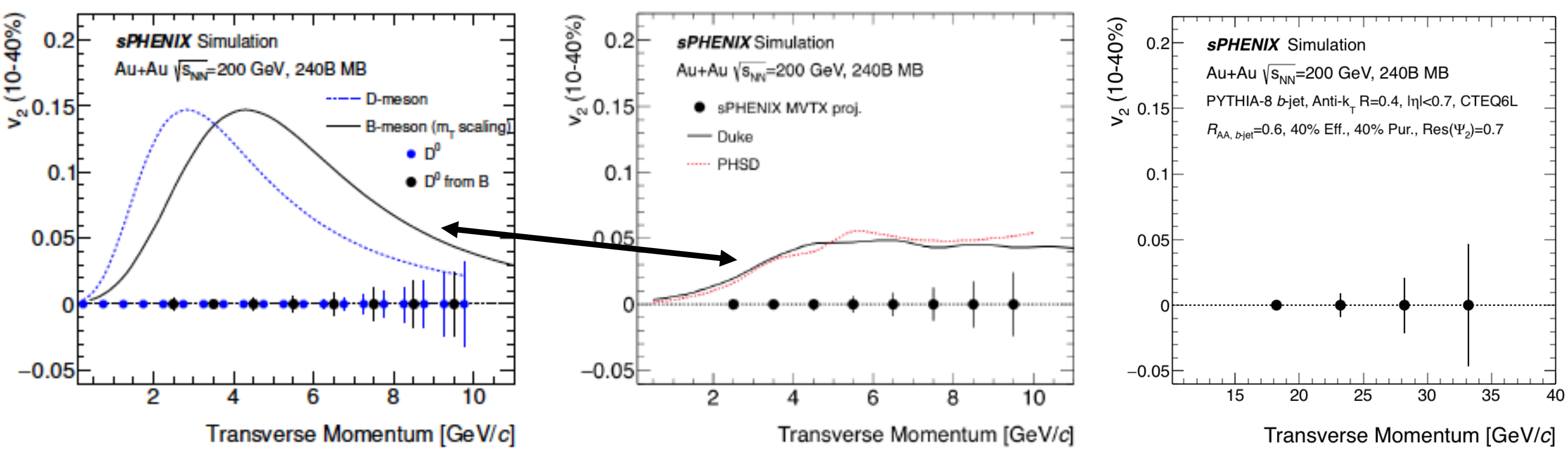


sPHENIX Project Elliptical Flow v_2

Open questions to be answered: nature of quasi-particles, medium interactions and transportation

B-Mesons

B-jets



More information

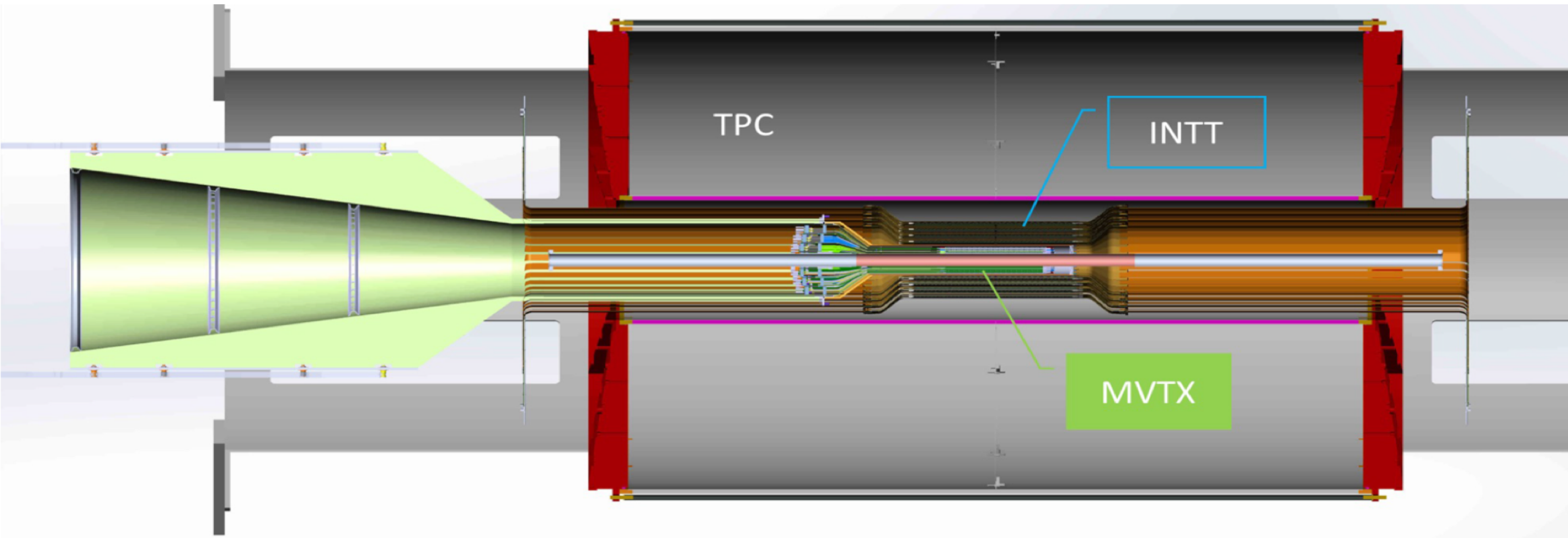
Summary: Major Remaining R&D

- Mechanical/Electrical integration with INTT+TPC
  - Carbon structure design
  - FPC extension

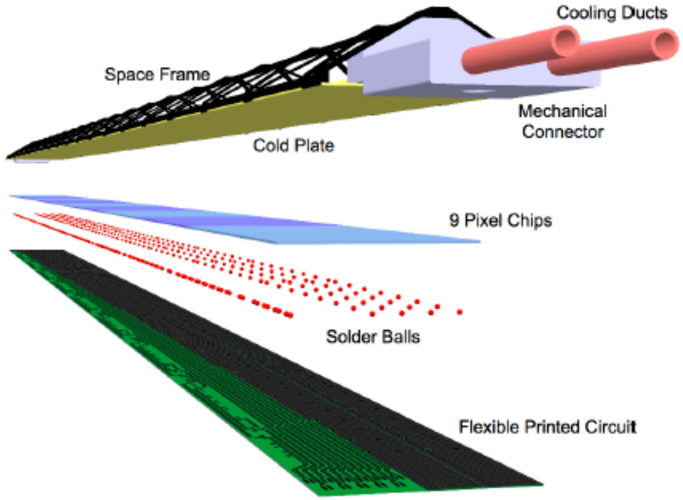
- Full electrical system control
  - Power
  - Safety
  - Online monitoring & controls
  - Integrate readout system firmware/software with slow controls

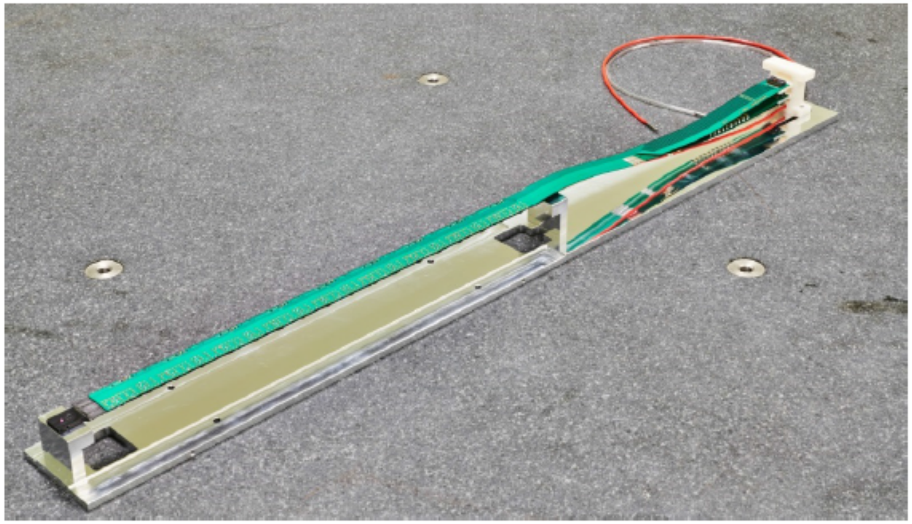
Mechanical Integration

sPHENIX Integration: MVTX + INTT + TPC



Effort & Plan on MVTX – Stave Assembly and Test





Radius (mm) 23, 31, 39
Nr. Staves: 12, 16, 20
Nr. Chips/ layer: 108, 144, 180

Length in z (mm): 271.2 mm
Nr. chips/ Stave: 9
Material thickness: ~0.3% X_0

Coolant Single-phase H_2O leak-less
Pixel operational temperature < 30°C
Pixel max temperature non-uniformity < 5°C
Chip Power dissipation < 50mW/cm^2

- Facility and technical resources are ready at CCNU for HIC assembly, and only replace assembly jigs
- Infrastructures need to be prepared for stave assembly (deploy a Coordinate Measurement Machine with identical tooling), and technical training is necessary
- HICs & Staves test setups

INTT-MVTX Conflict

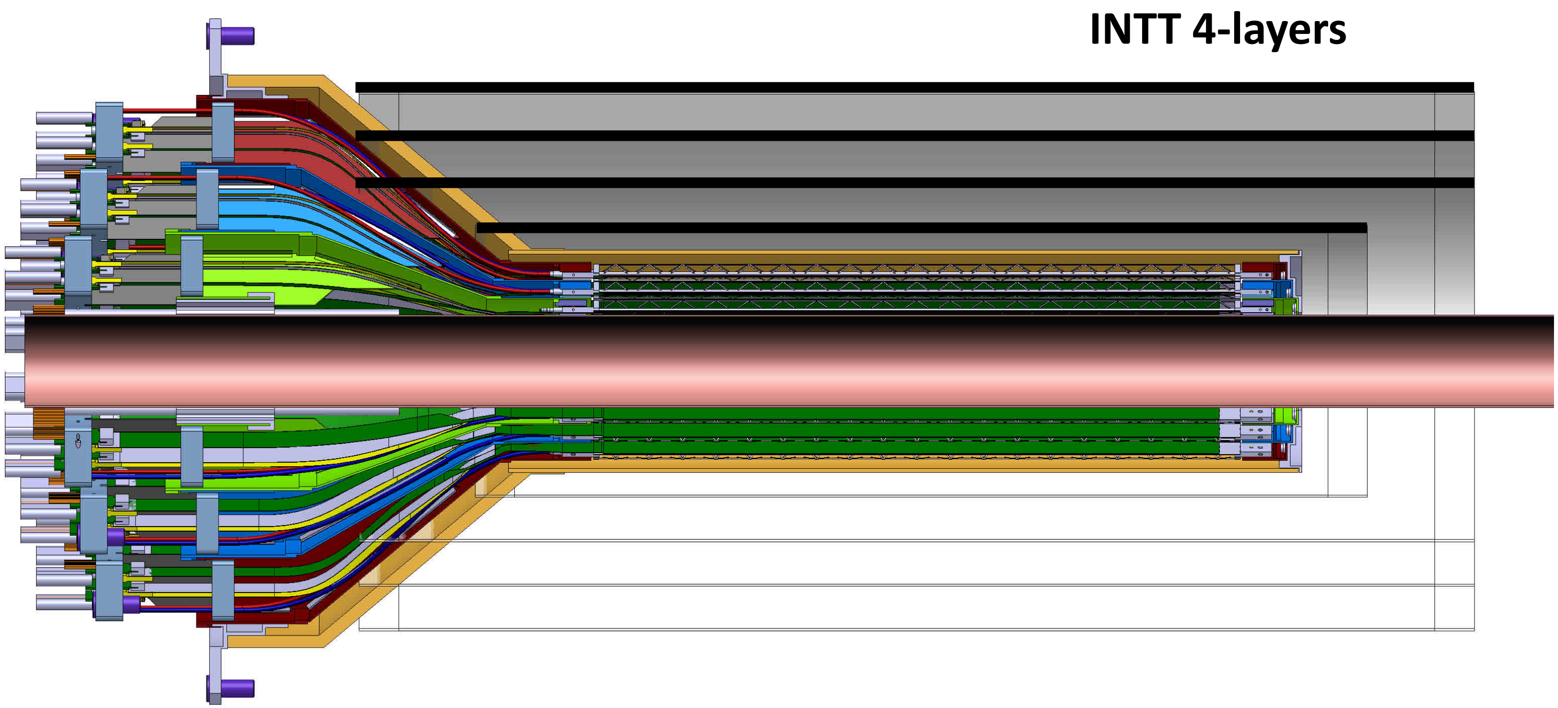
INTT Acceptance
@ |z|=10

$|\eta|<0.95$

$|\eta|<1.09$

$|\eta|<1.28$

$|\eta|<1.12$

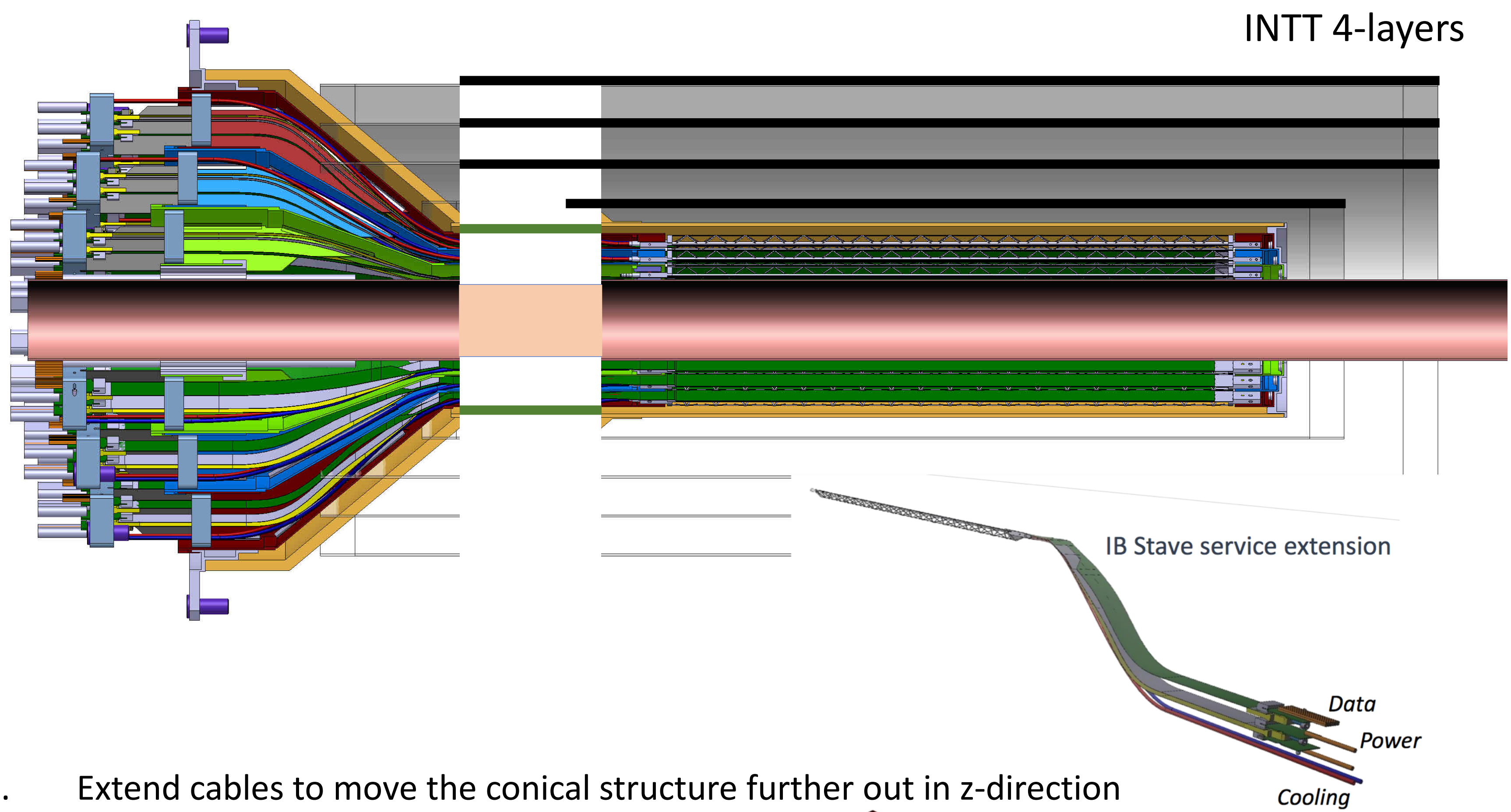


- Currently a clear conflict between the INTT and MVTX
  - INTT only includes ladder, no connectors, cooling barbs, etc

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

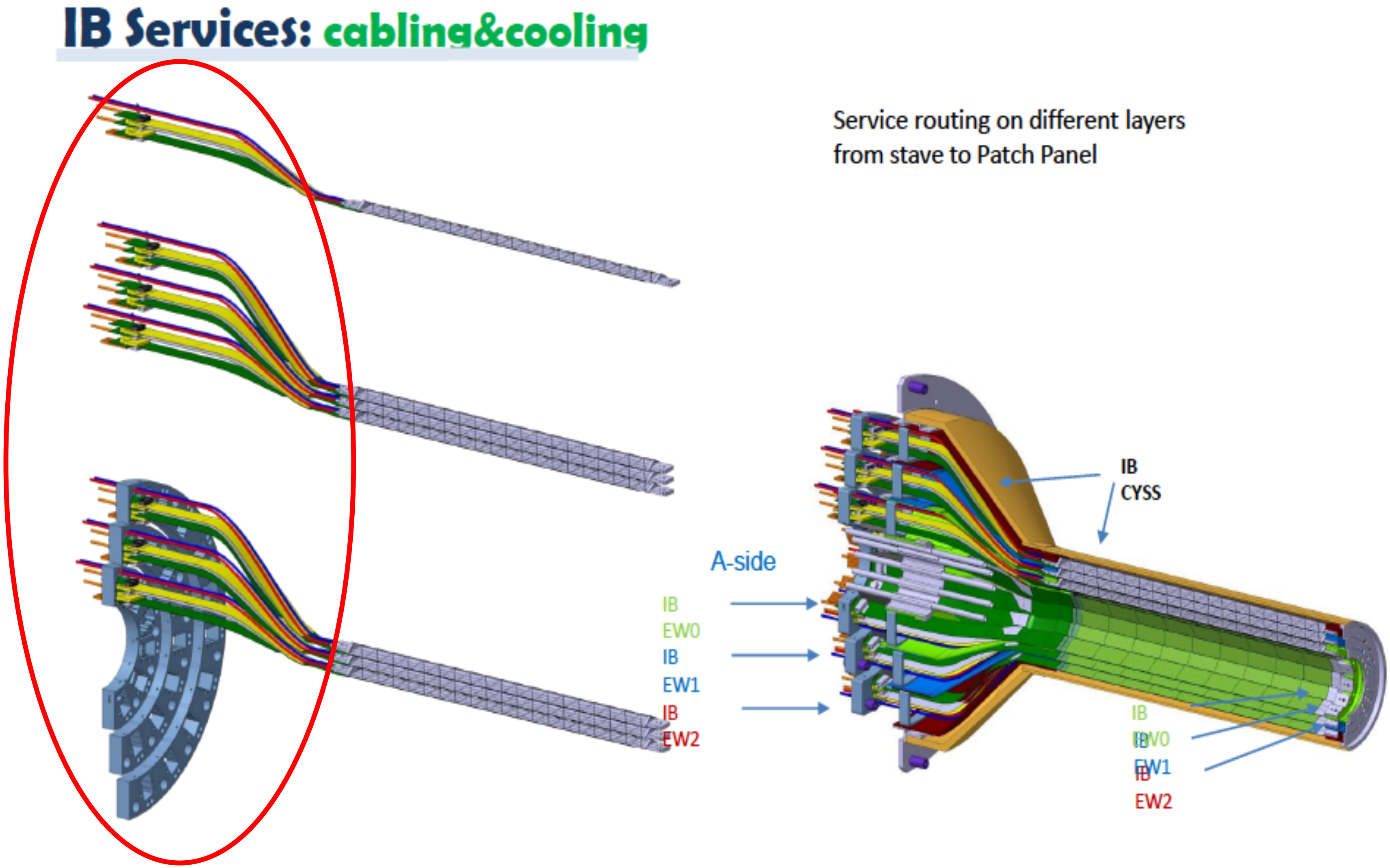
- FPC data cable is the HDI and can't be easily extended, short "firefly" cables possible?
- Reduce angle of cone – redesign C-structures and connectors

INTT-MVTX Conflict



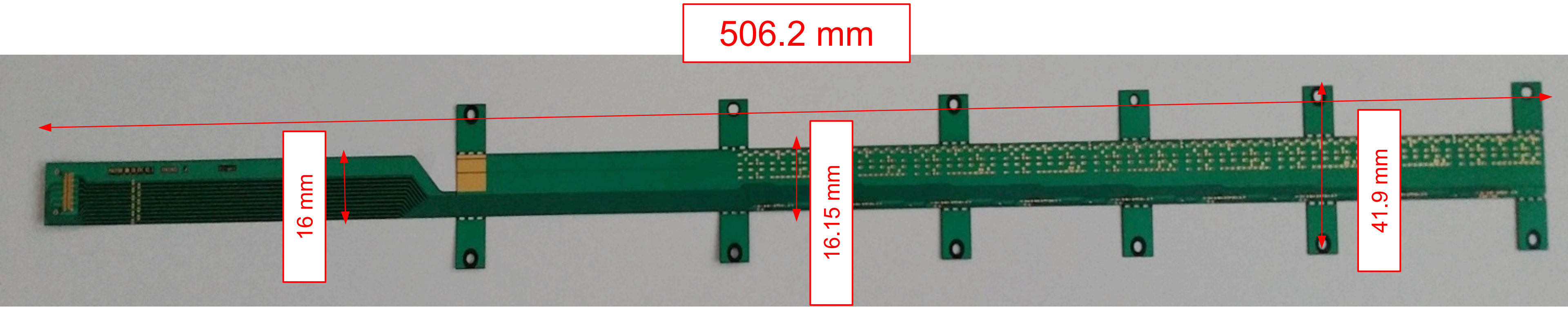
1. Extend cables to move the conical structure further out in z-direction
   - FPC data cable is the HDI and can't be easily extended
   - Possibly add short "firefly" cables to hook up to patch panel, R&D needed
2. Reduce angle of cone – redesign

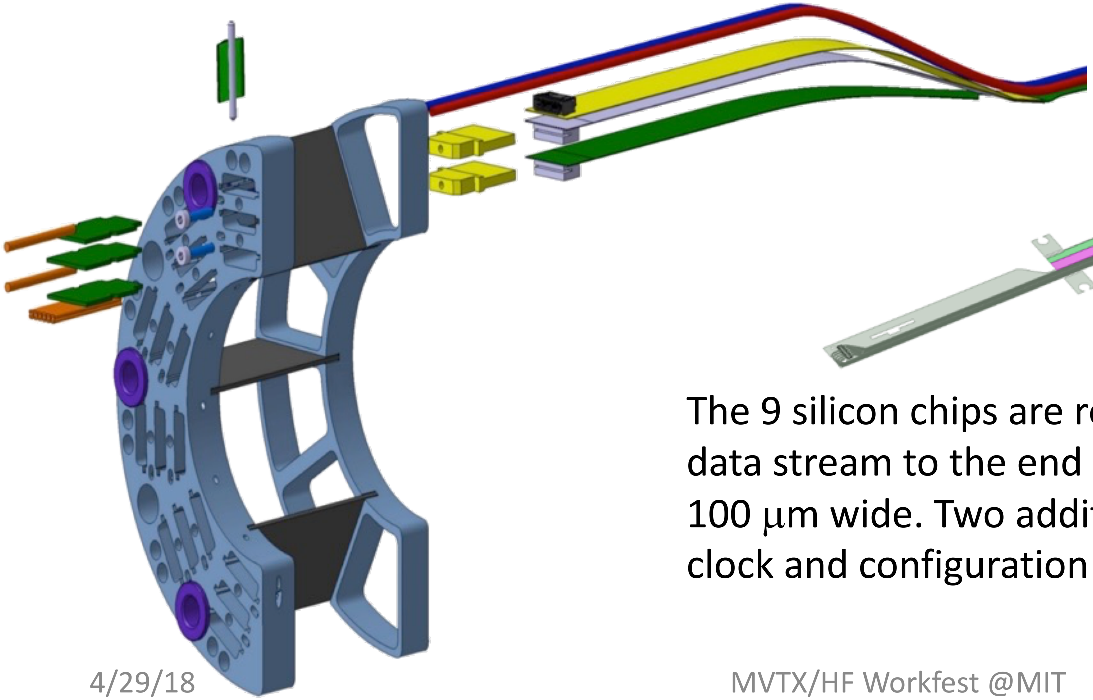
Signal and Power Extension for FPC

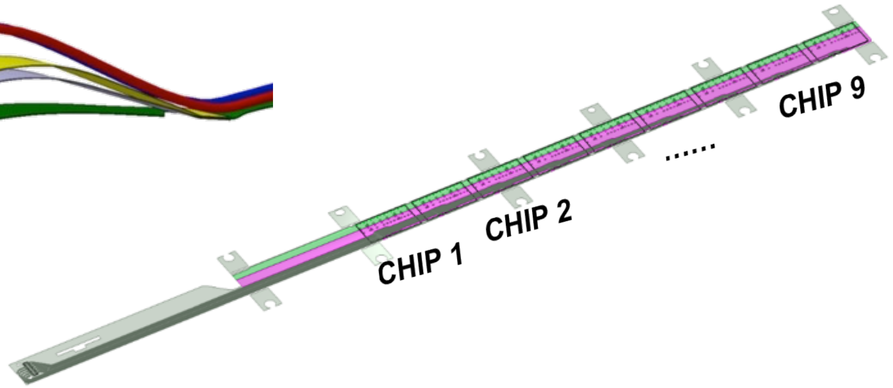


MVTX/INTT Integration

Extend MVTX Service Cables?

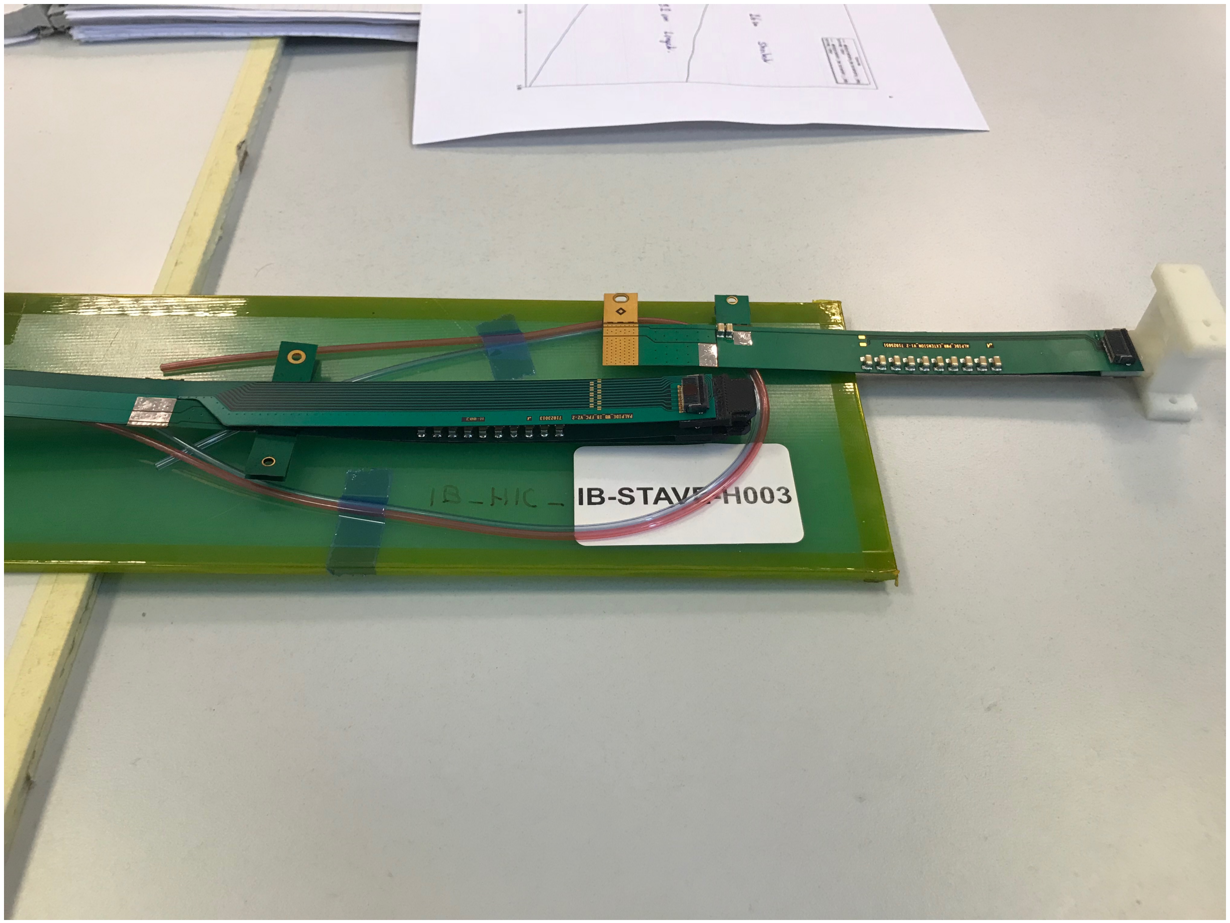


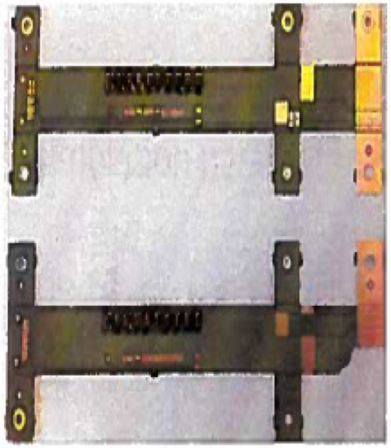


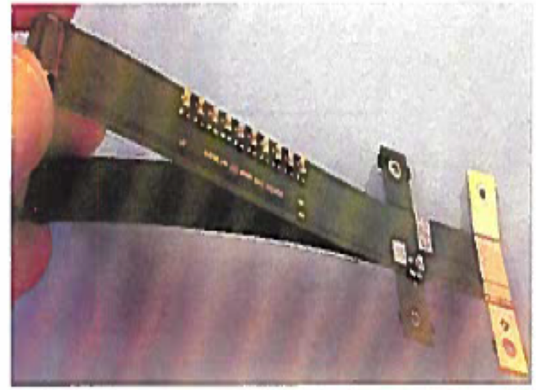


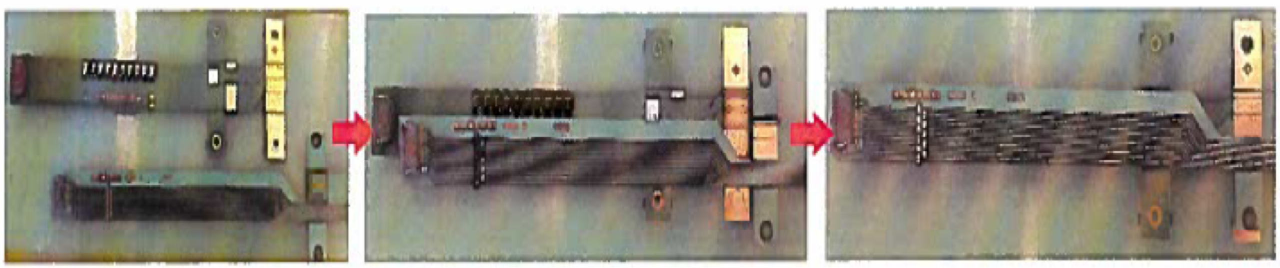
The 9 silicon chips are read out in parallel: each chip sends its data stream to the end of Stave by a dedicated differential pair, 100 μm wide. Two additional differential pairs distribute the clock and configuration signals.

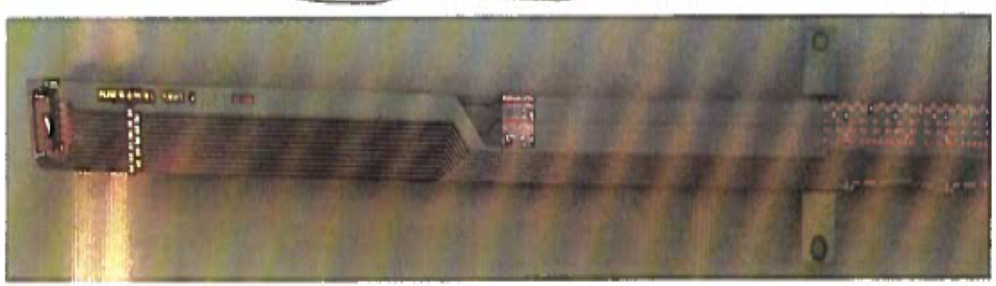
MVTX FPC R&D @CERN and LANL





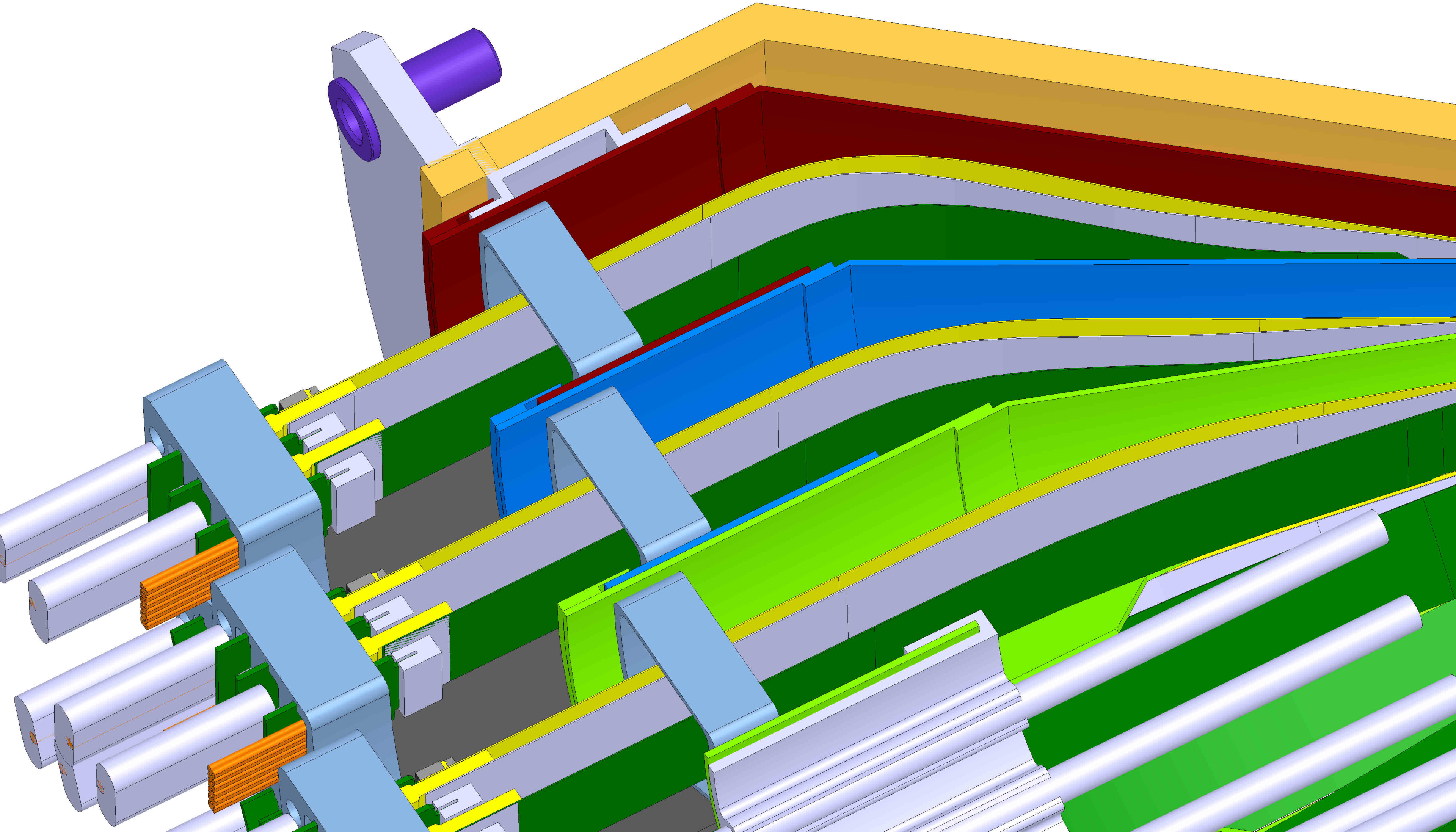




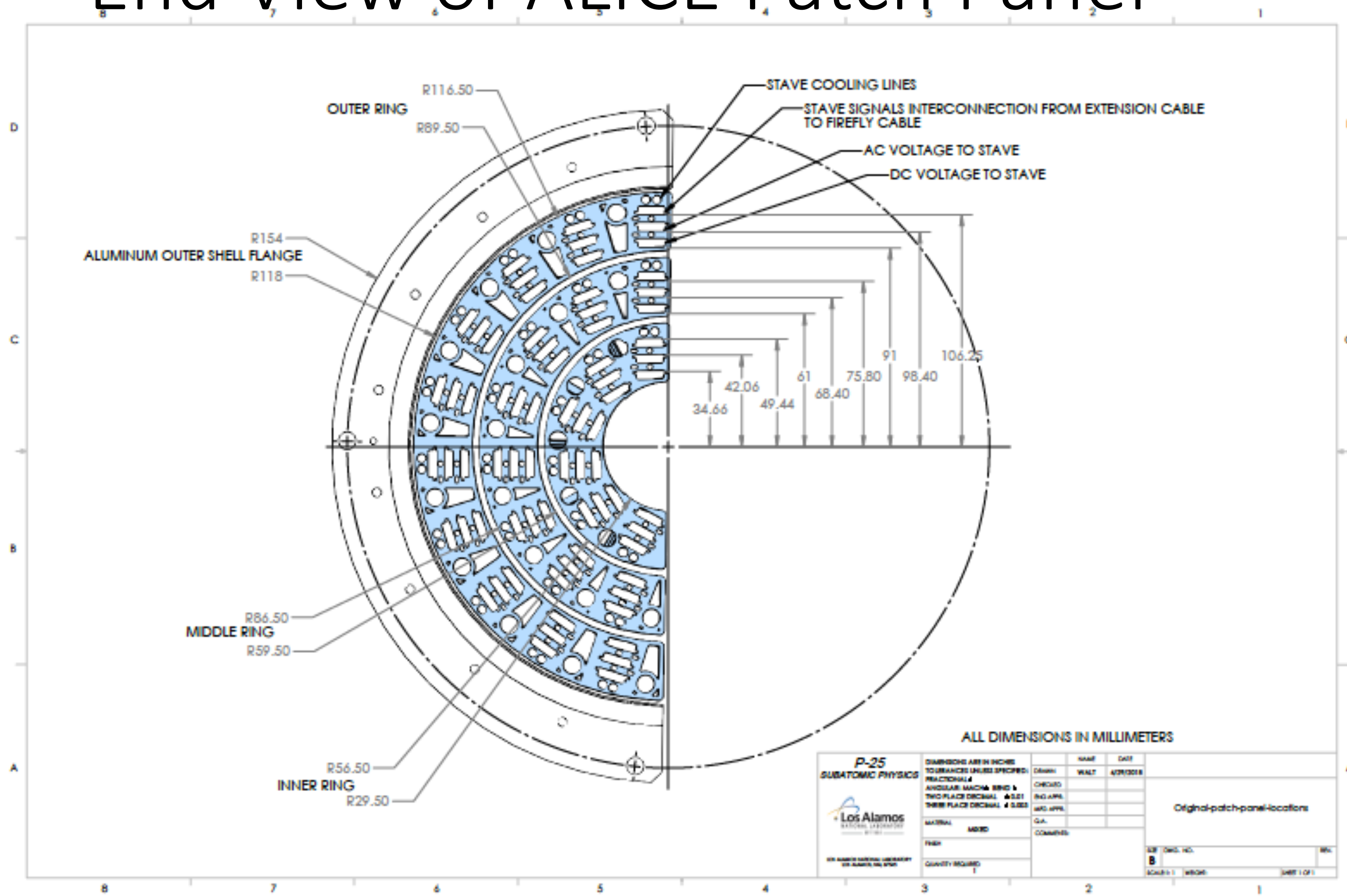


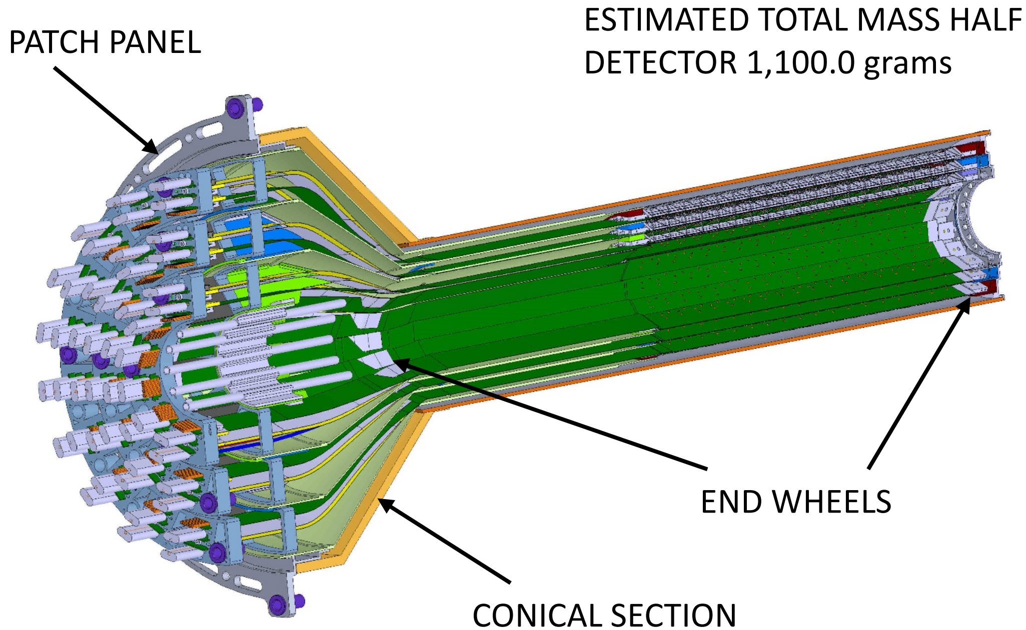
IB FPC

11



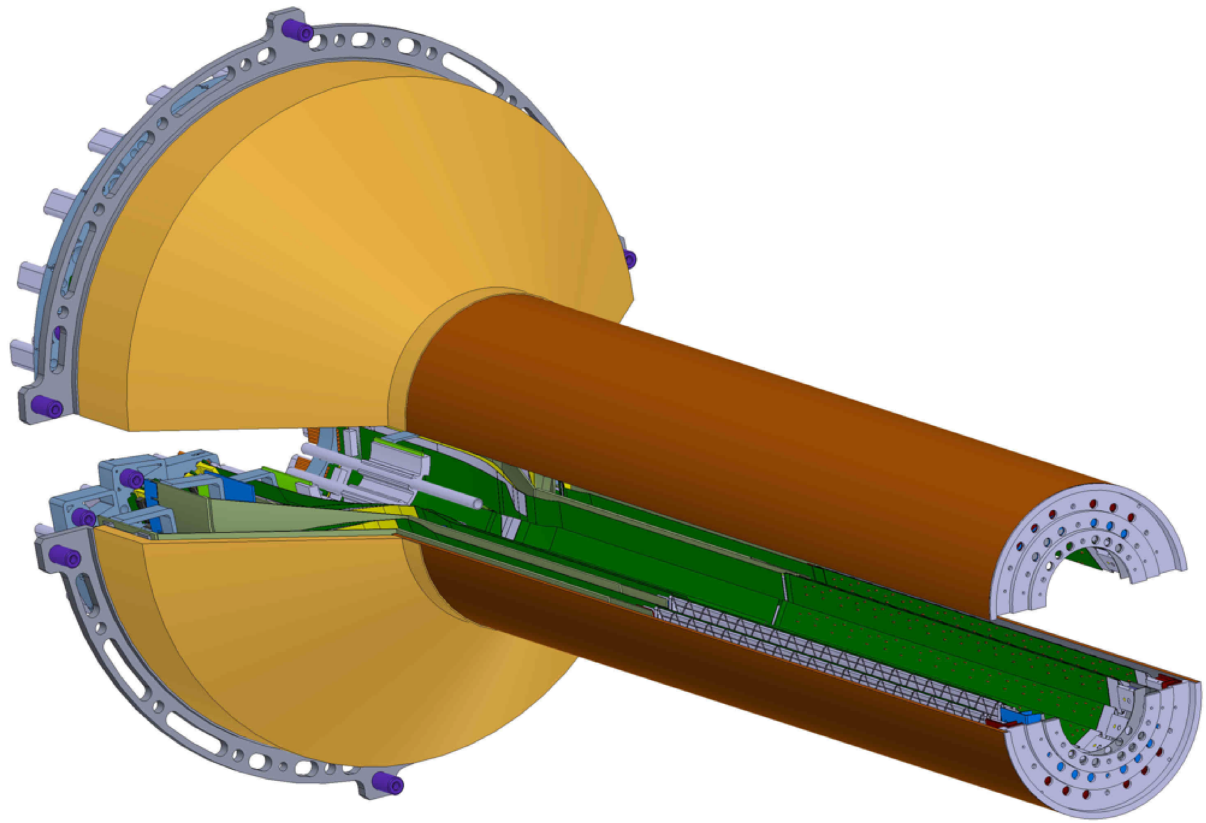
End View of ALICE Patch Panel



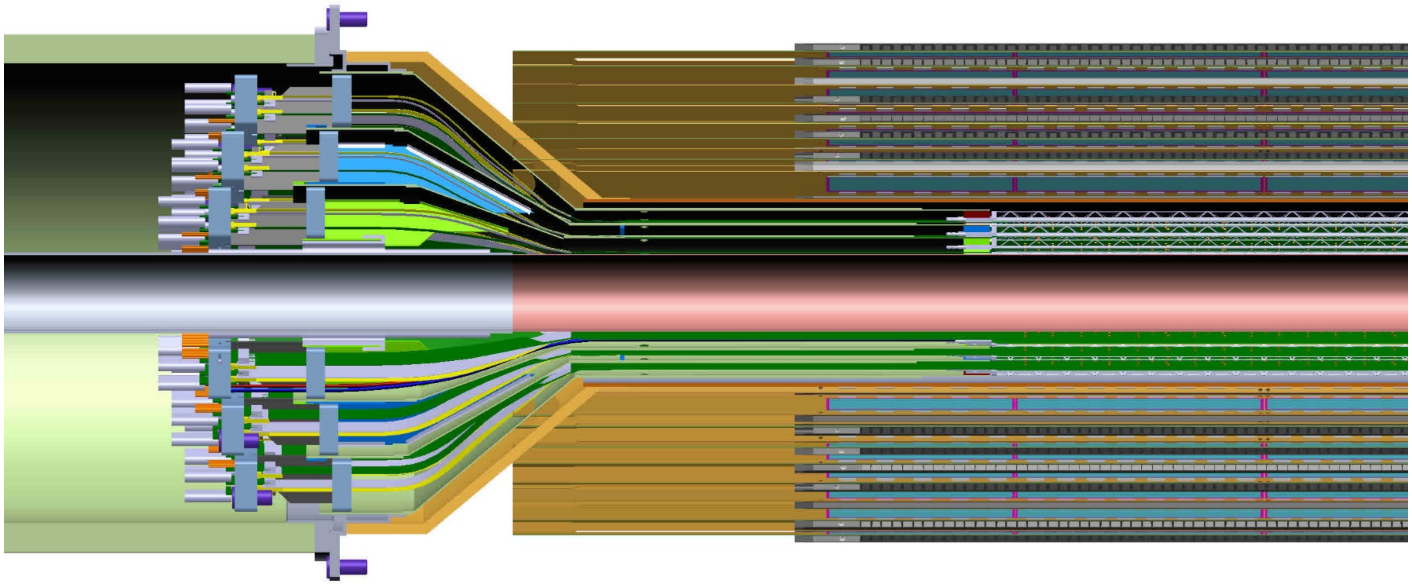


MVTX half detector assembly

MVTX Detectors

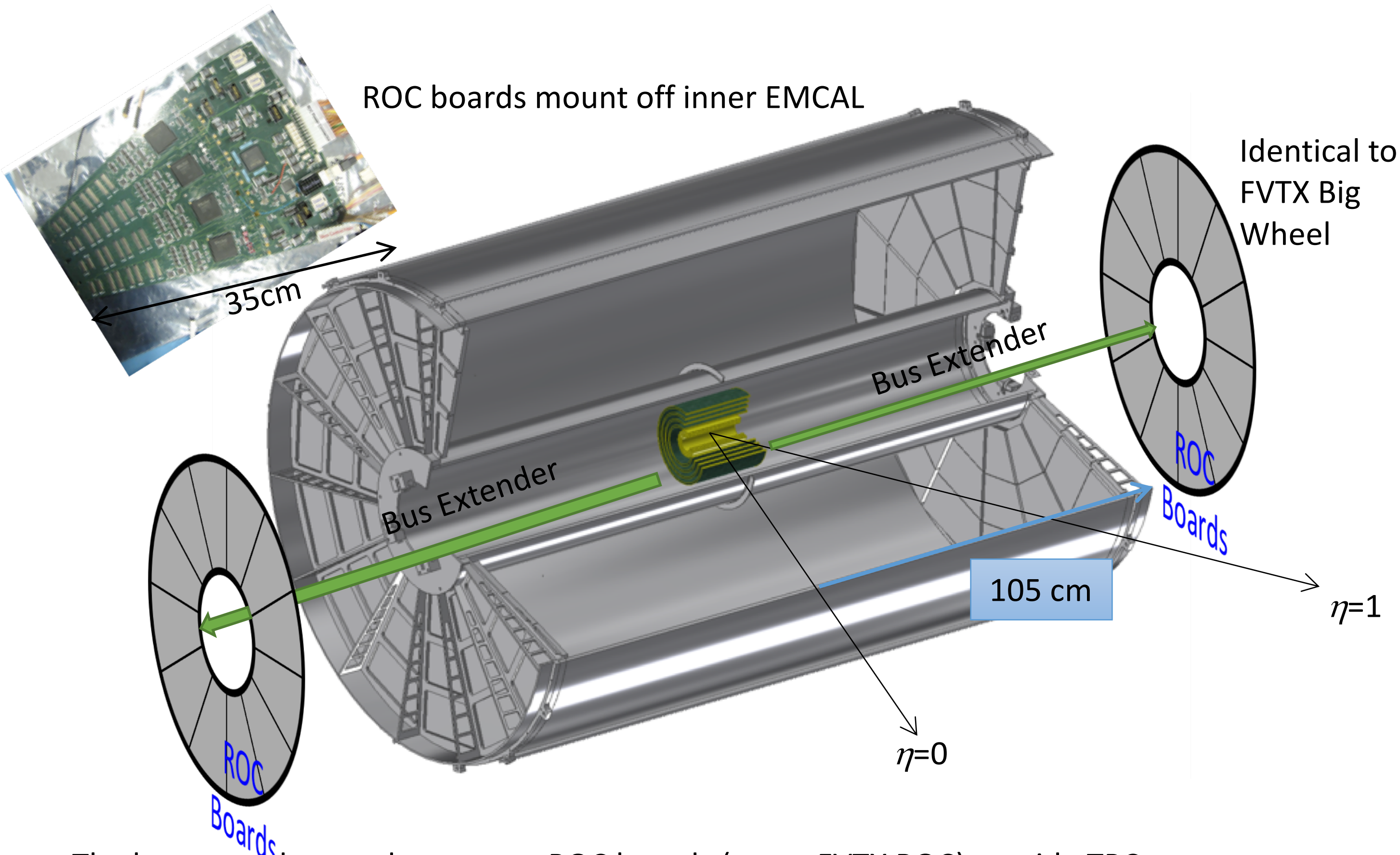


MVTX and INTT Integration – Work in Progress



It is clear from this detail view the conical region of the MVTX detector barrel with the INTT that the MVTX will need to translate in Z…

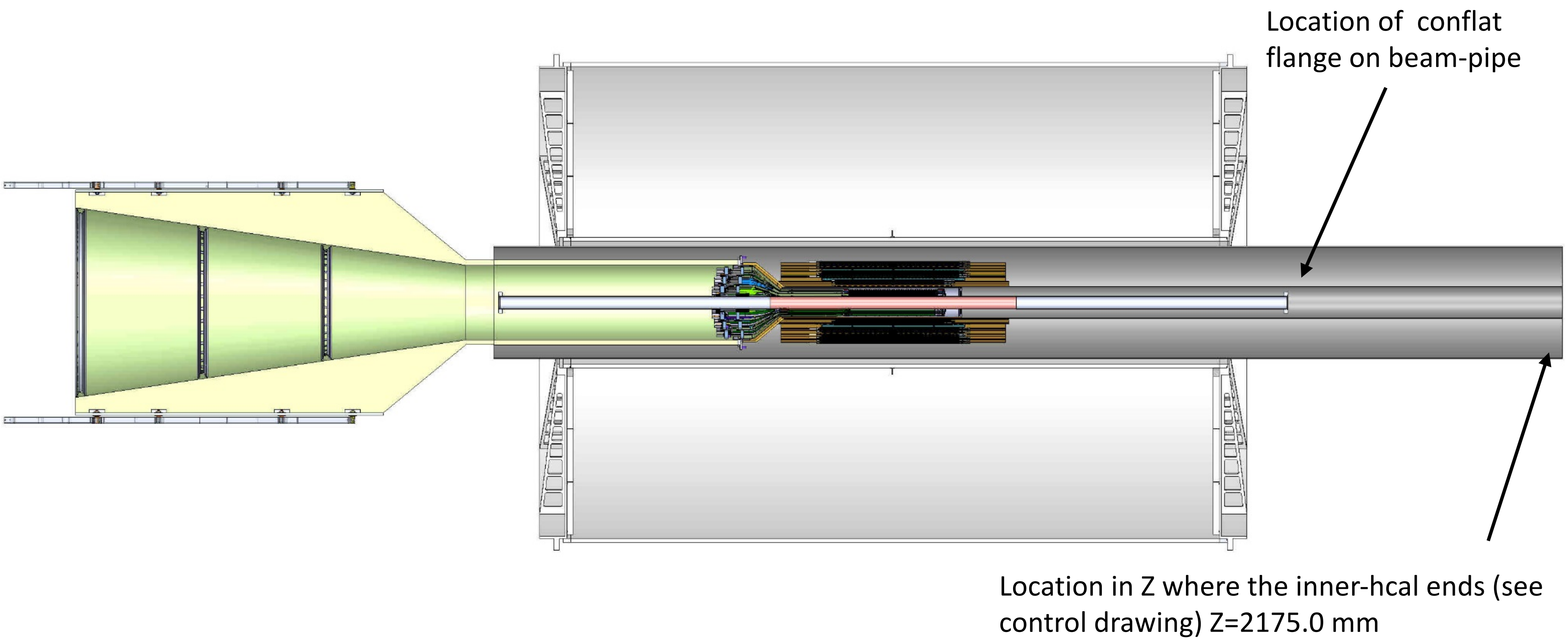
INTT Readouts from both North and South



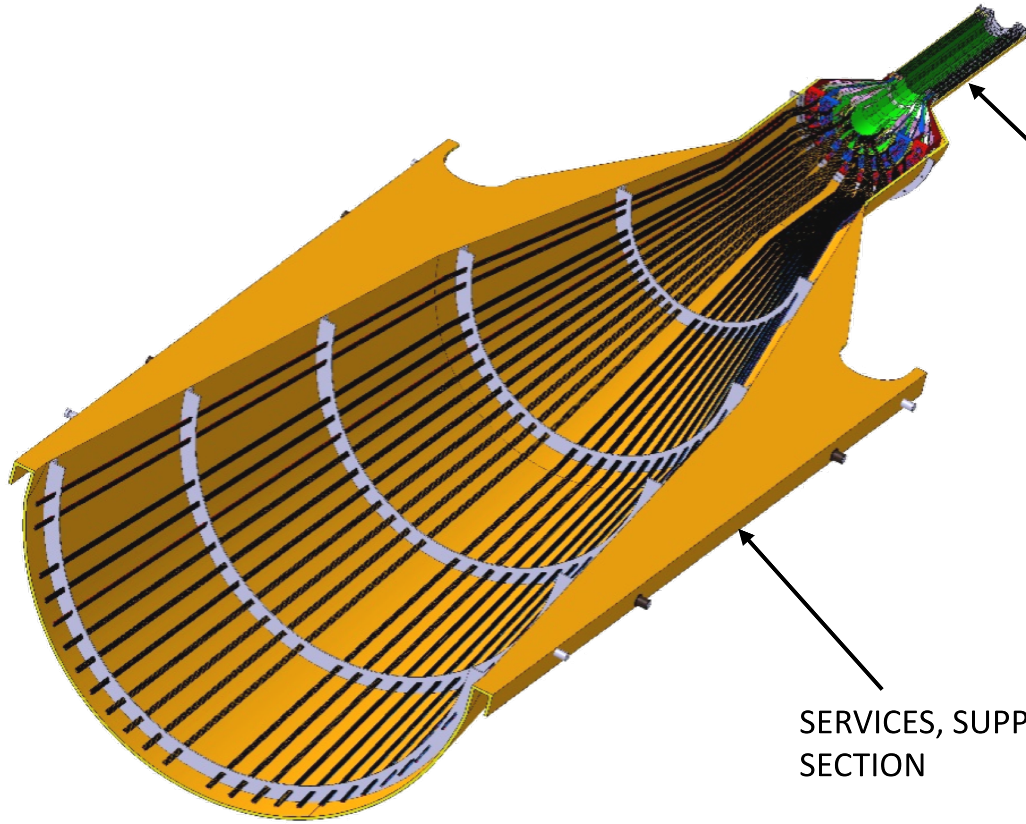
The bus extender needs to run to ROC boards (reuse FVTX ROC) outside TPC.
Minimum length is 105cm – ladder length + distance to ROC board.

Mechanical Integration

Model of MVTX with INTT inside TPC with the addition of two concentric composite cylinders;



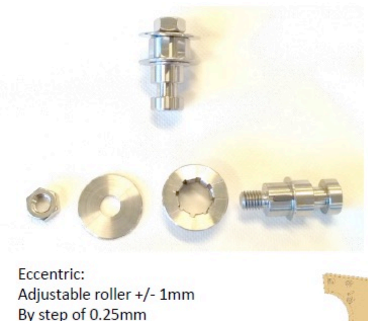
Service Barrel: Design and Fabrication



ALICE HALF-BARREL ASSY

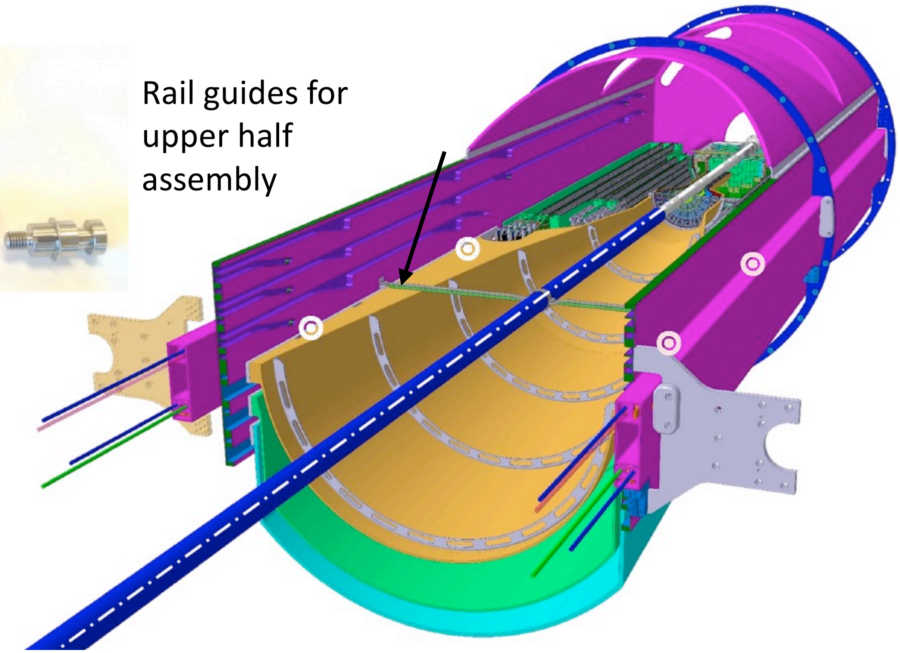
ALICE Inner Tracker Rail Support

The MVTX plus INTT half barrel assemblies location position is provided by the engagement of 4 rollers on the half-barrel, which would be previously measured and aligned, into four precise inserts housed in the “cage-rail” assembly.



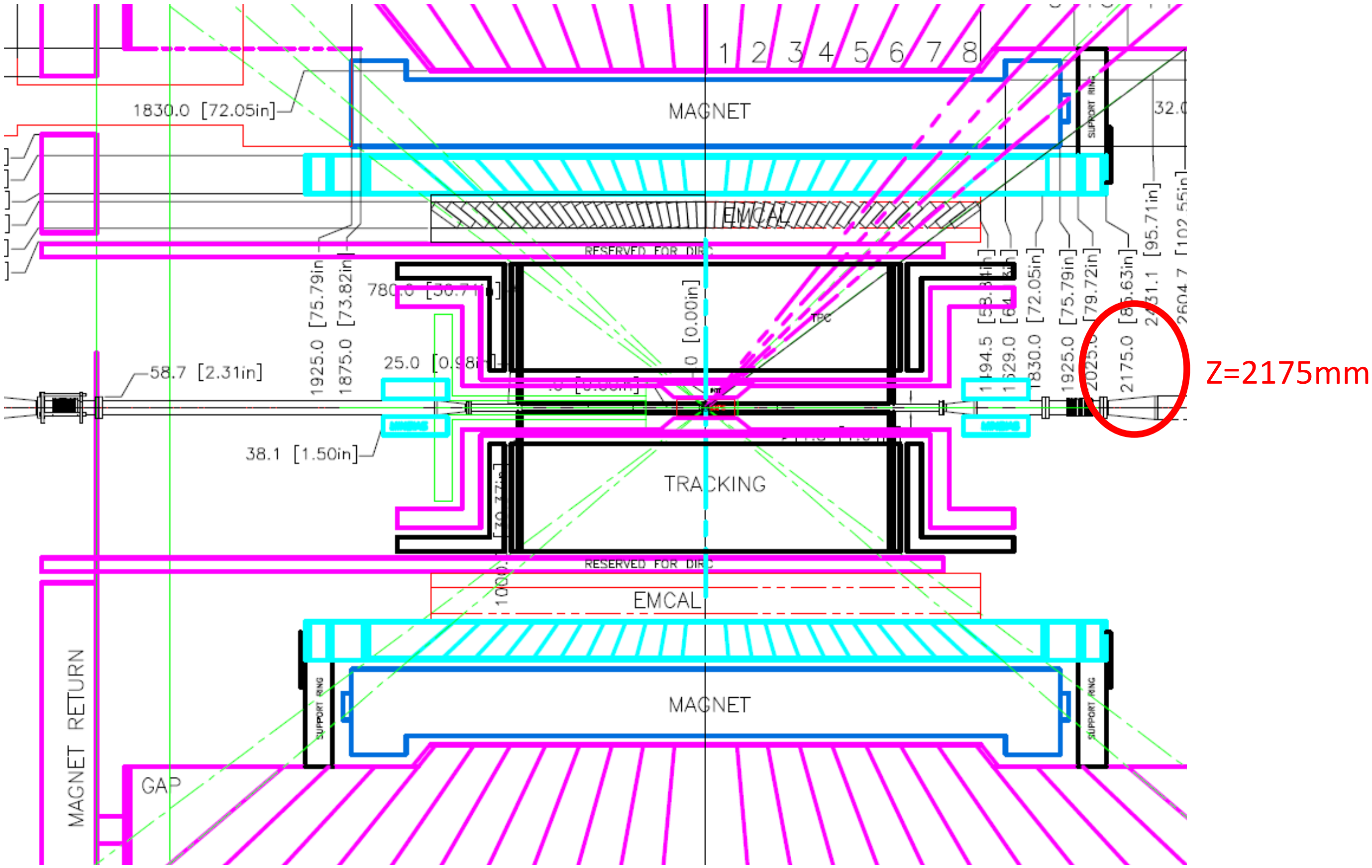
Eccentric:
Adjustable roller +/- 1.0 mm, by steps of .25 mm

Rail guides for upper half assembly

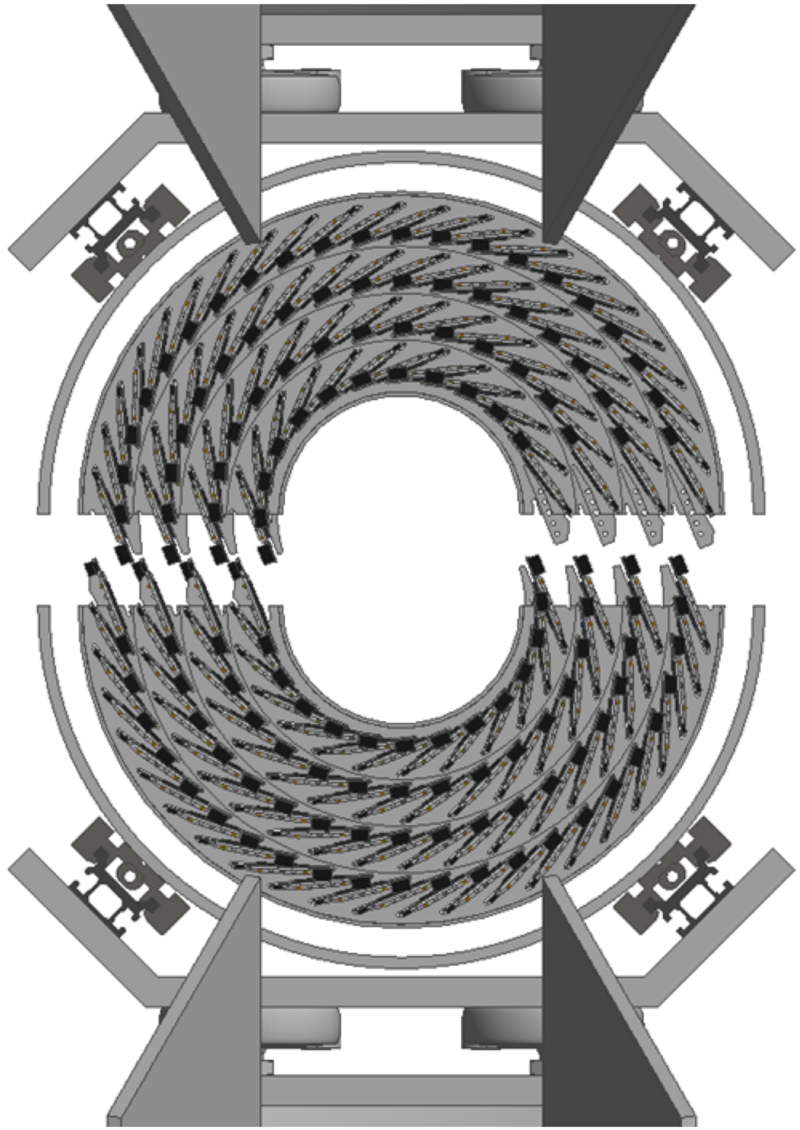


In sPHENIX we will not use a “service cone, rail system” anywhere near the size of that planned for the ALICE detector, but we will use their concept.

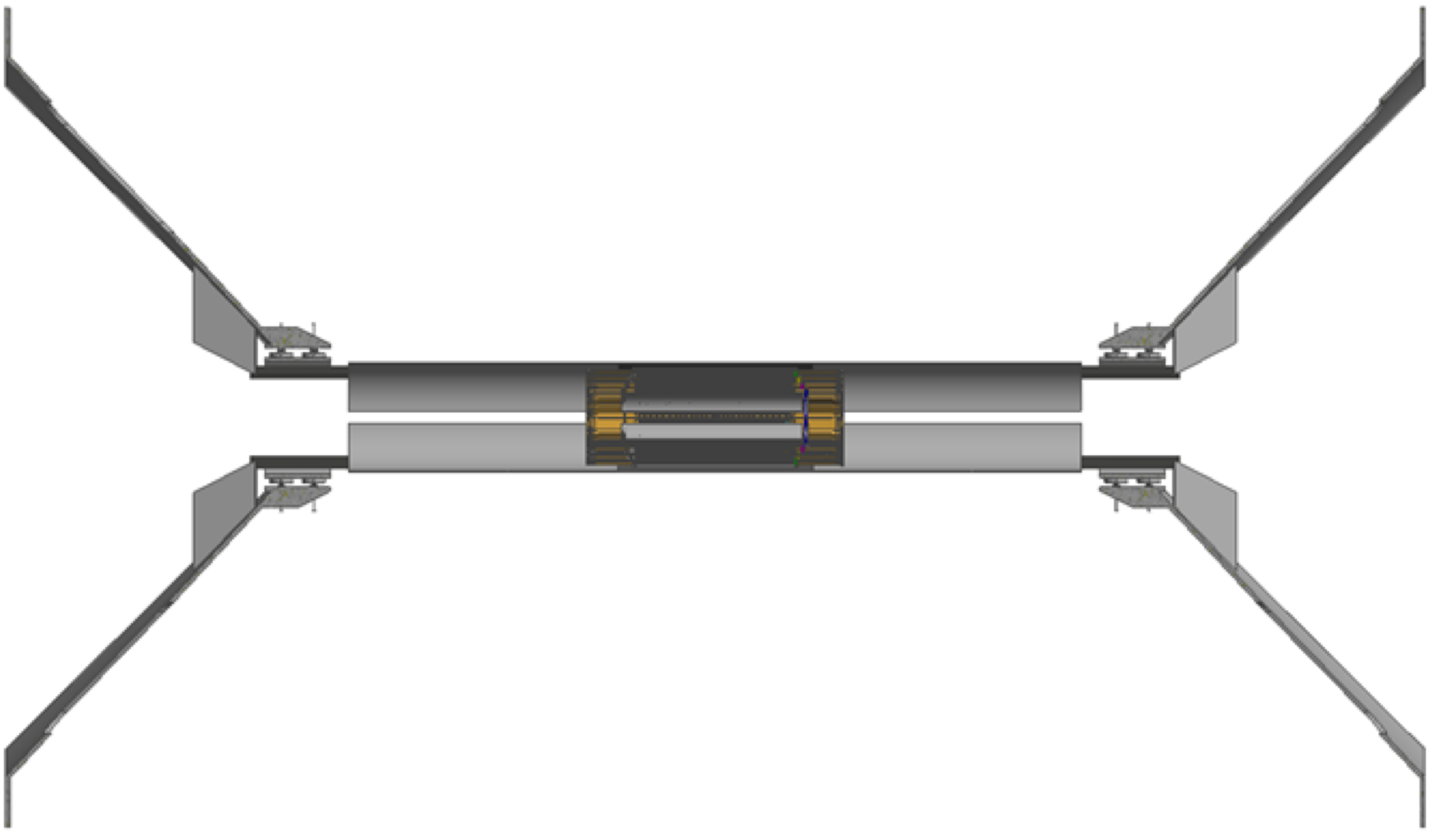
BNL control envelope drawing; Z location of the inner hcal is at 2175,0mm



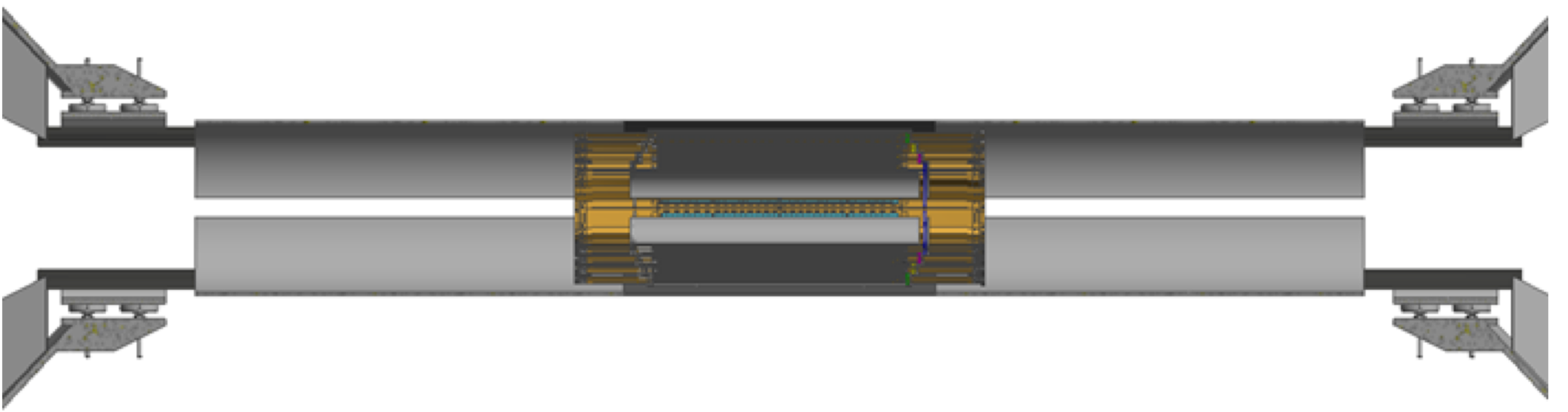
INTT



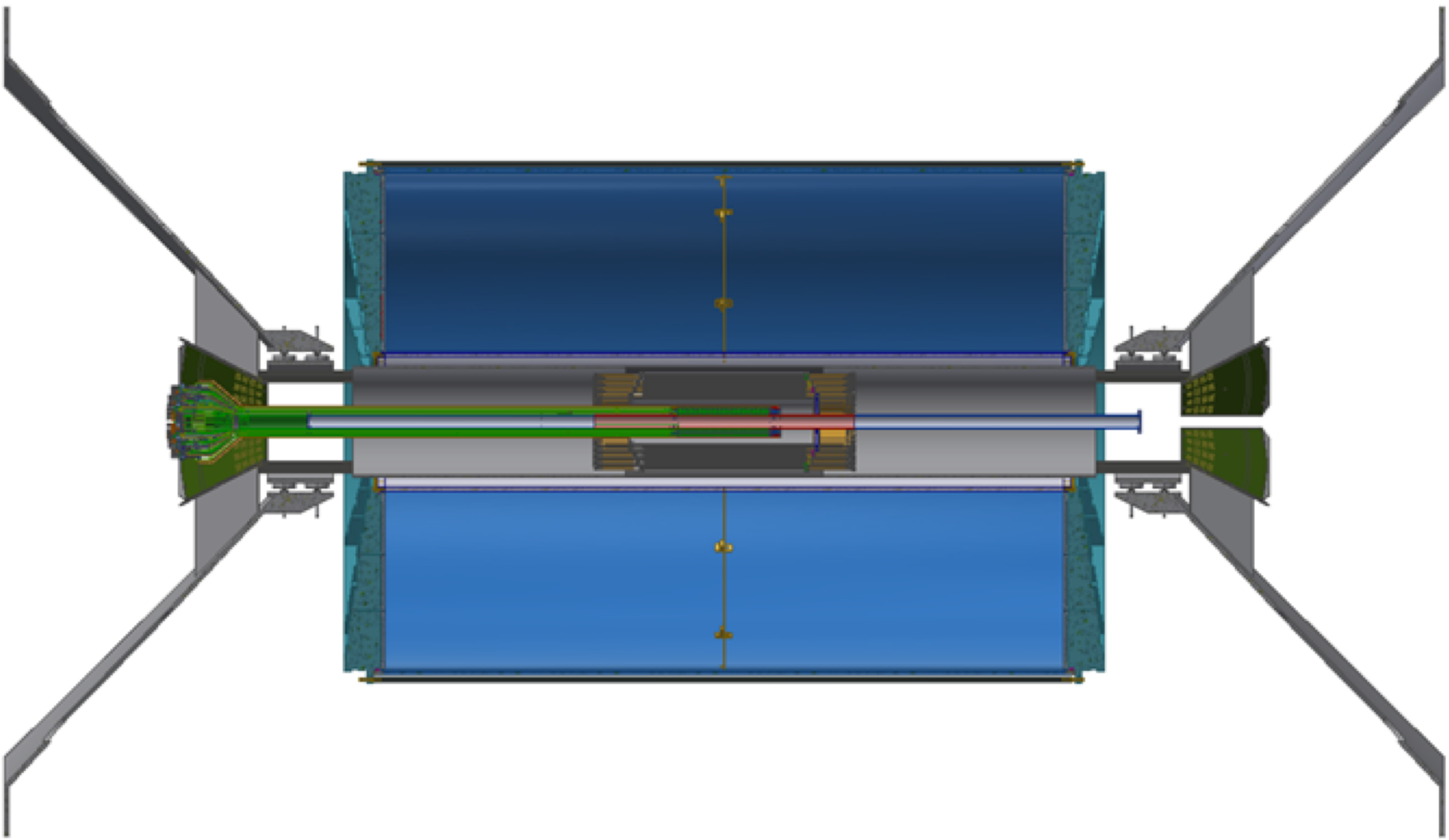
INTT



INTT

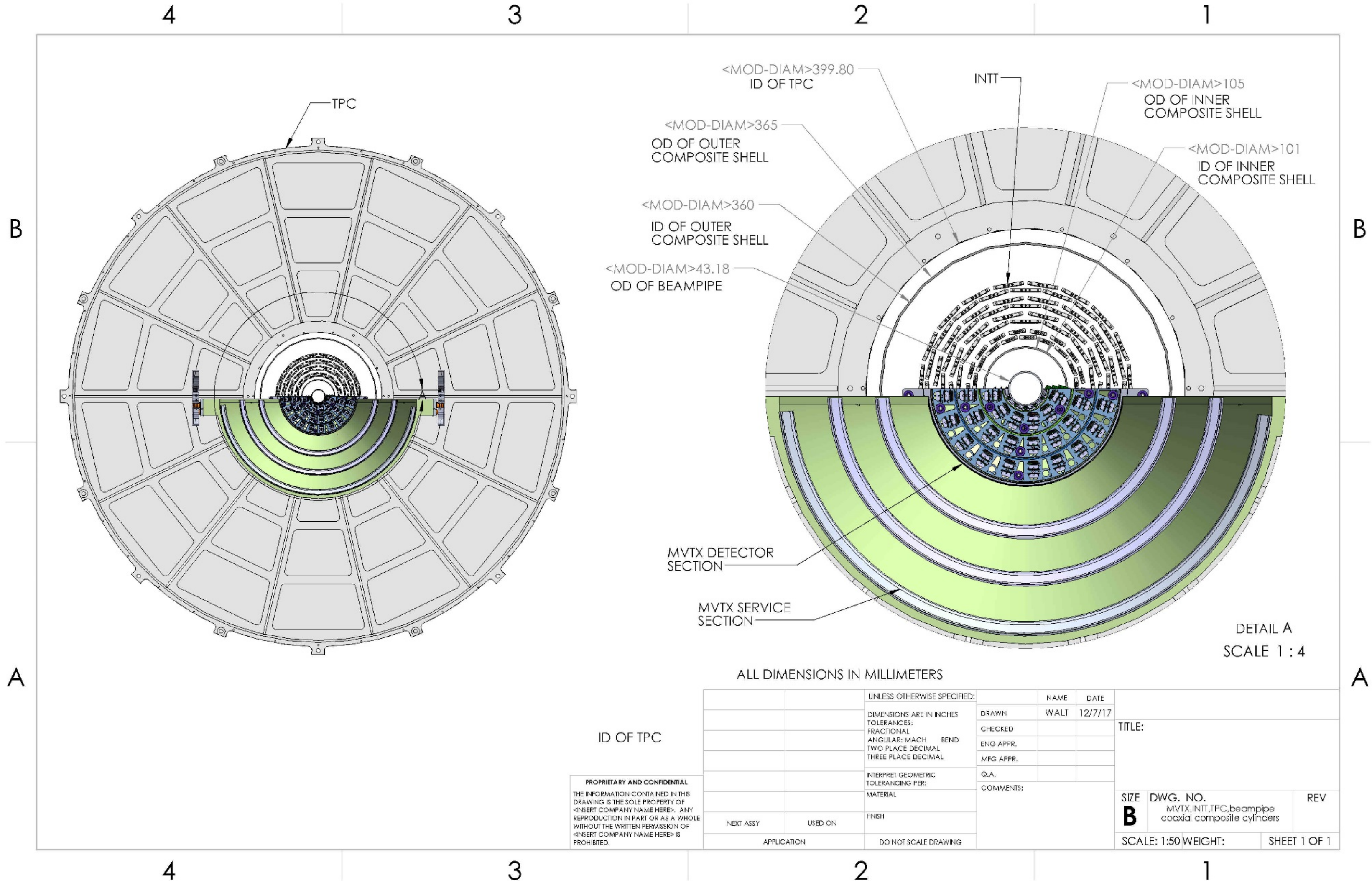


MVTX + INTT + TPC

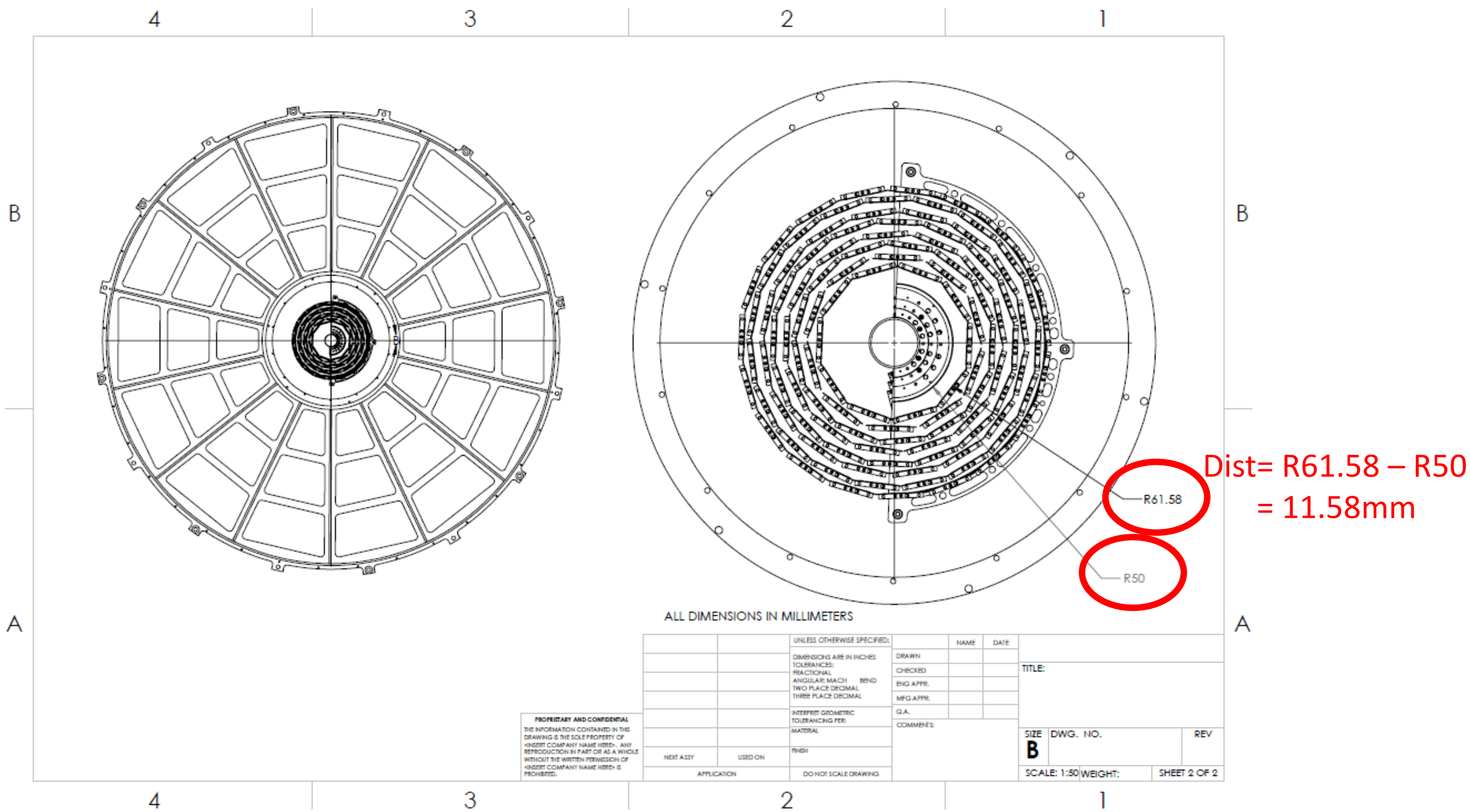


Cross-section view from CAD model of MVTX, INTT, TPC, beam-pipe, plus two composite conical shells:

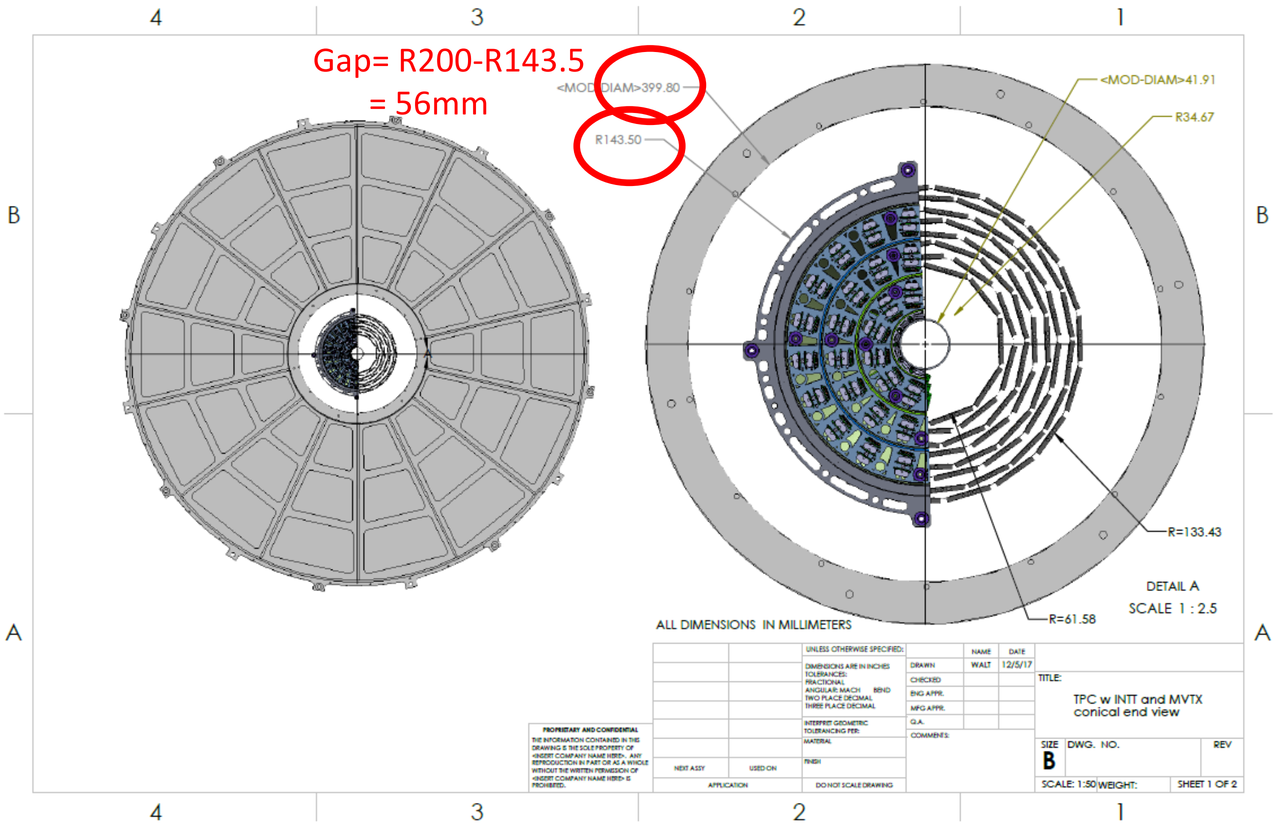
MVTX radius are increased by 1.5mm to have a minimum 2mm gap between beam pipe and then inner MVTX structures



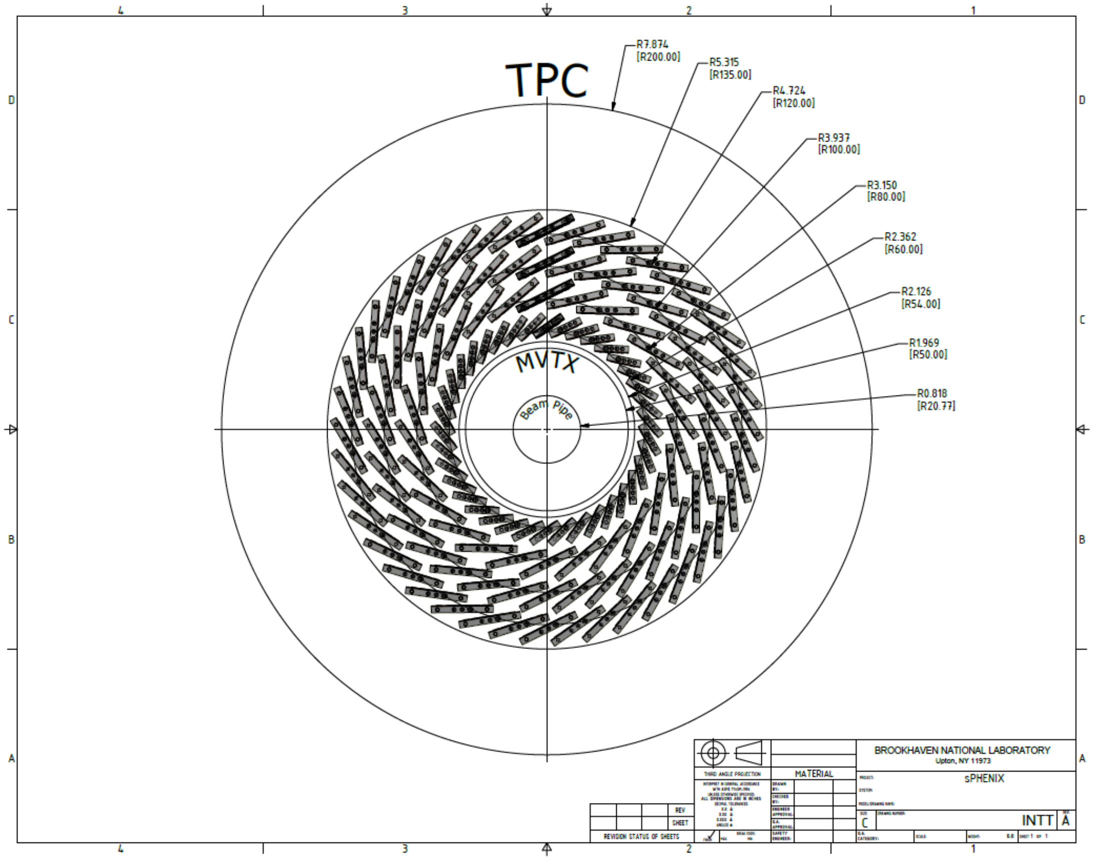
Gap between conical shell of MVTX and inner layer of INTT is 11.58 mm



56.0 mm gap between INTT and inner radius of TPC

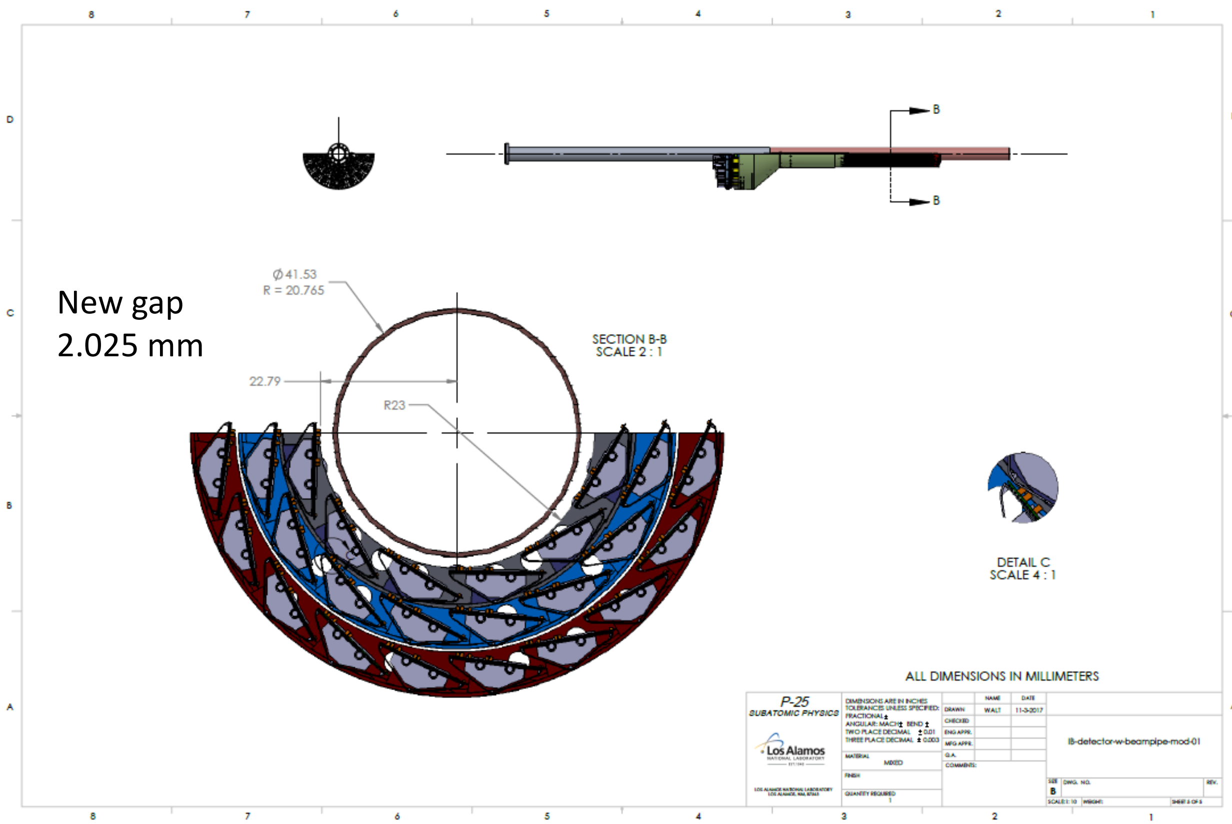


Earlier model for the INTT, chevron configuration, inner layer half ladders in width;

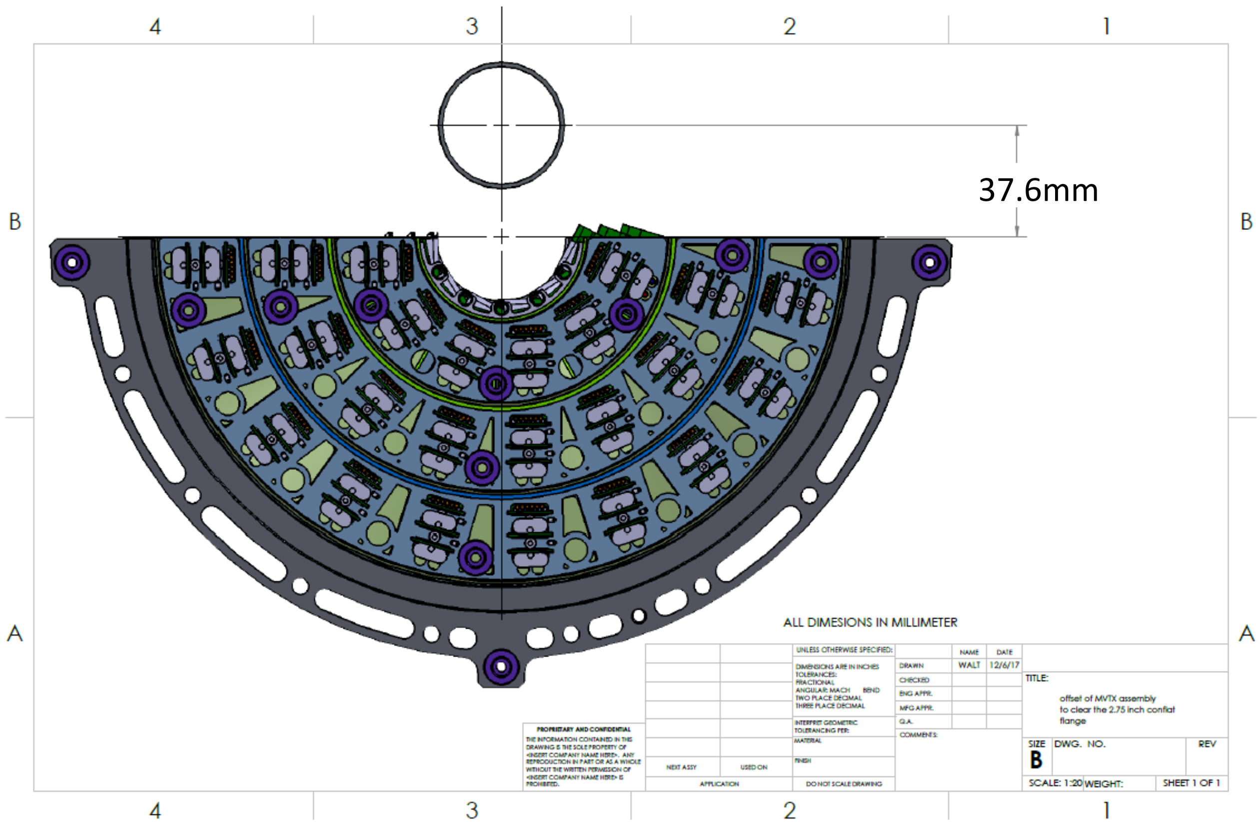


Number of ladders:
Layer 0 – 38 half ladders,
Layer 1 – 26
Layer 2 – 34
Layer 3 - 42

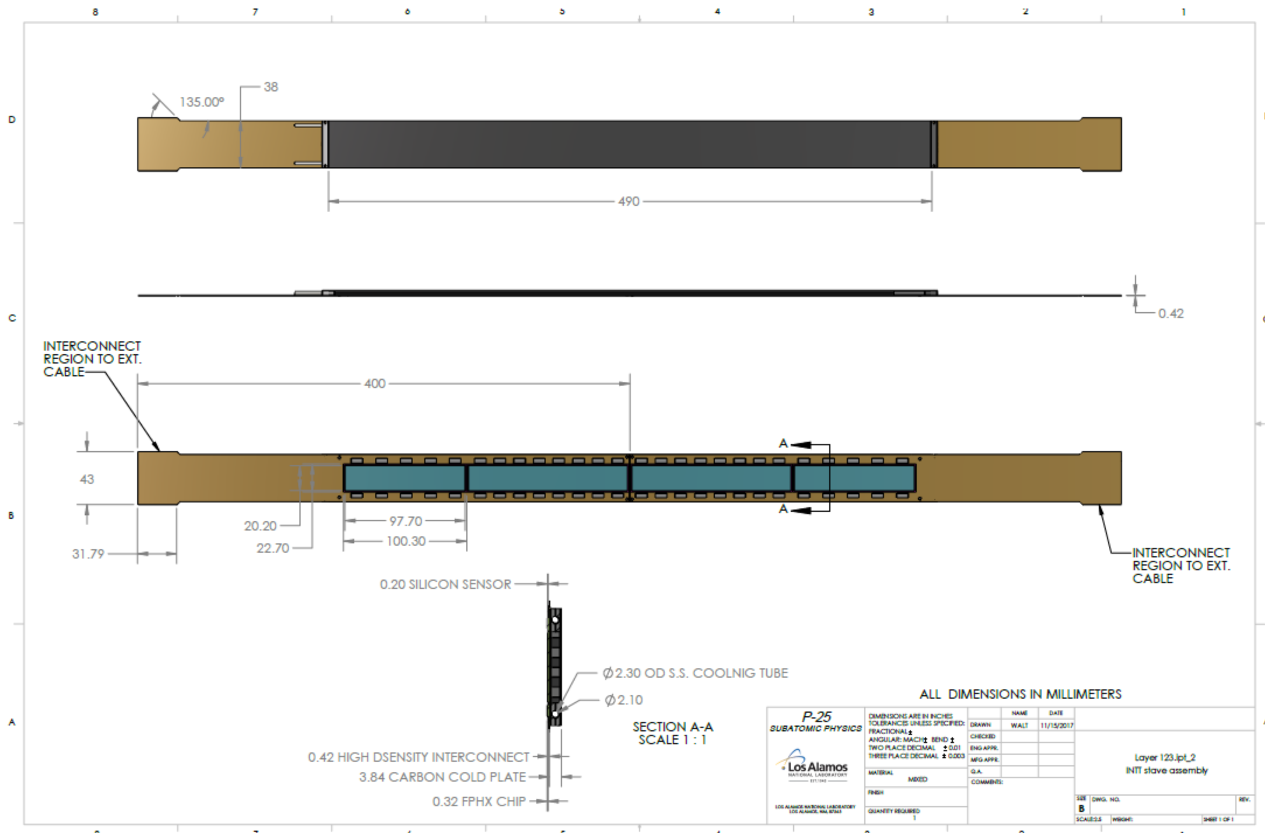
Offset from OD of beampipe and innermost component of the MVTX



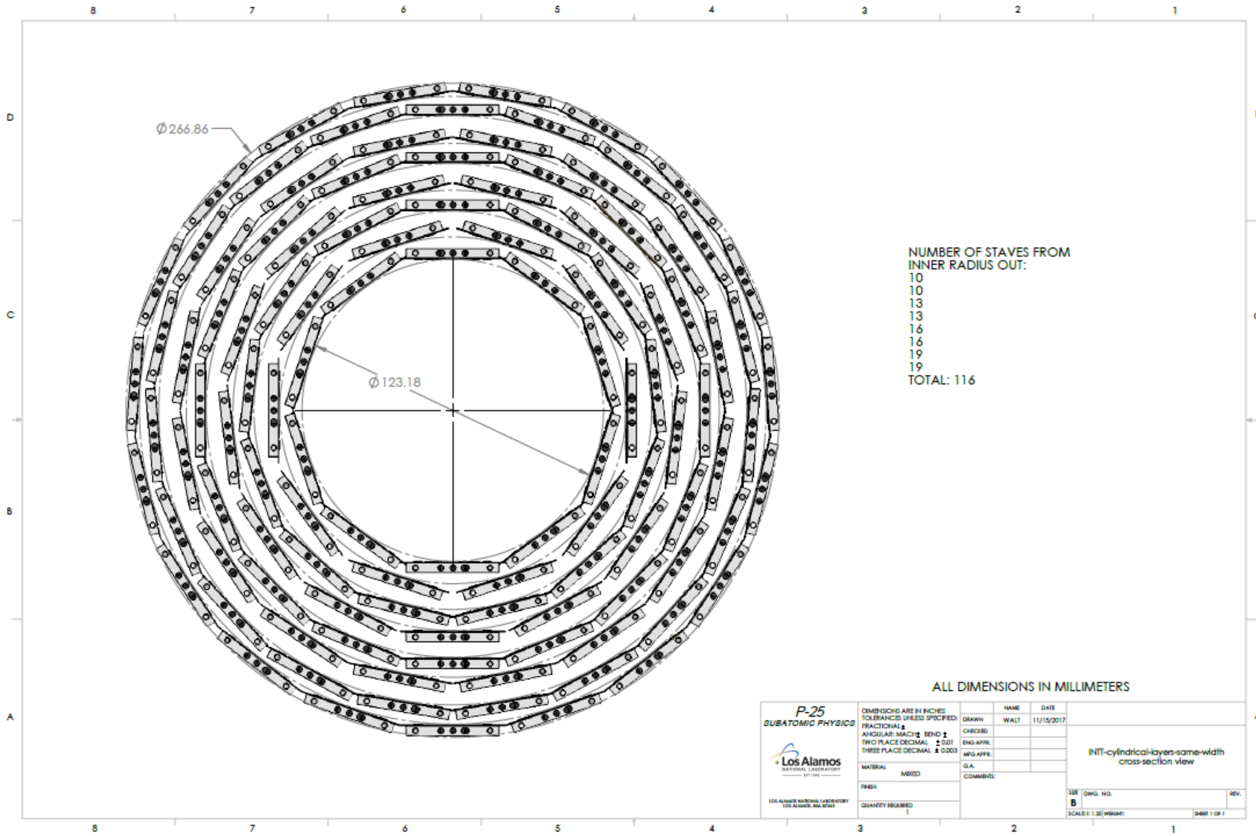
Offset needed to install split MVTX into run location around beampipe, passing over 2.75 in conflat flange



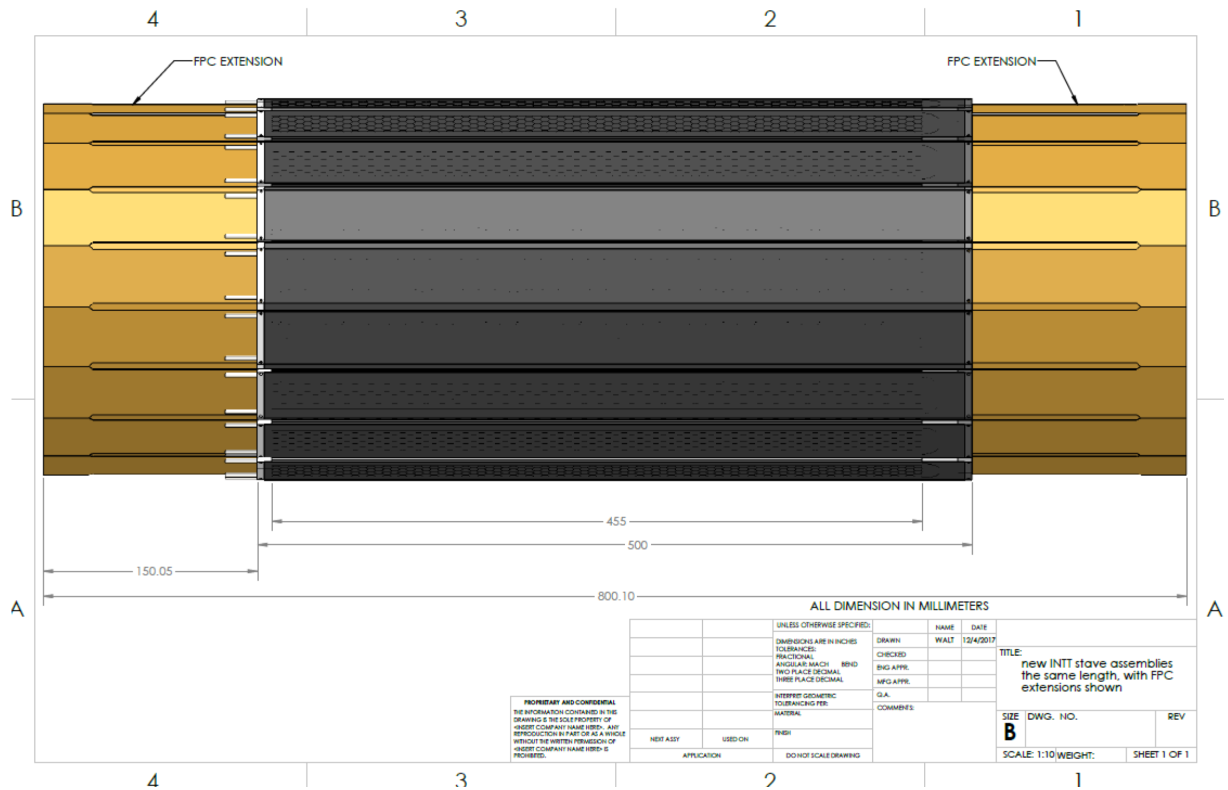
INTT stave design with HDI



Latest configuration of ladders in the INTT, 4 layers where each is made from two layers for hermeticity



New INTT model with HDI extensions;



Cost & Schedule

Cost and Schedule in the Full Proposal

- Total budget: 6.5M
    - Production
    - Assembly
    - Integration
- About 9 months schedule float

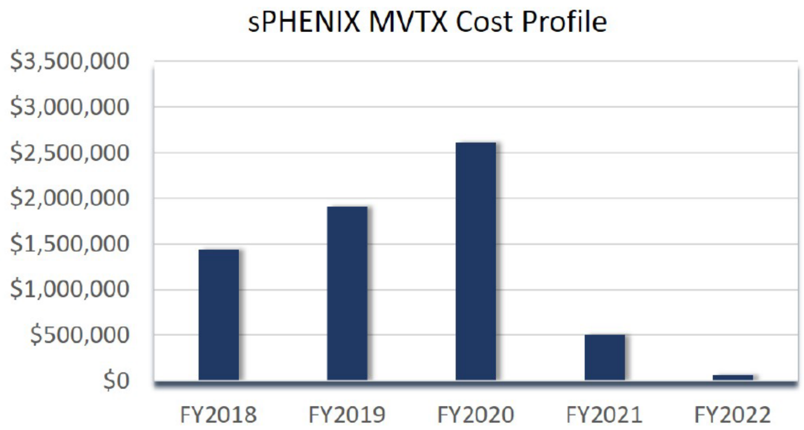
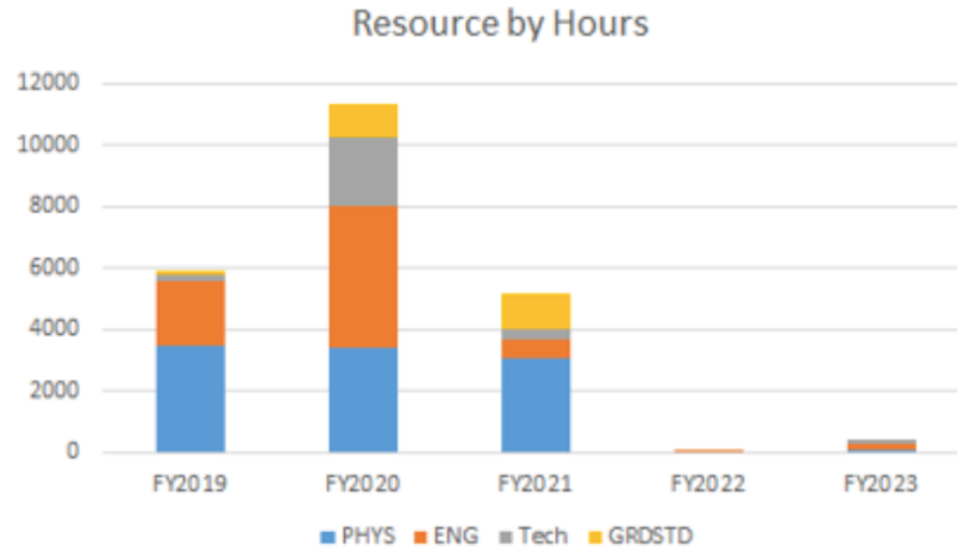


Figure 42: MVTX Funding Profile.

Major Items	Cost ($M)	Schedule
Staves (WBS 1.5.3.1)	1.3	8/2018-5/2019
Readout & Controls (WBS 1.5.2)	1.3	1/2019-6/2019
Mechanics & Detector Assembly (WBS 1.5.3)	1.8	2019-2022, TBO
Integration (WBS 1.5.4)	1.0	2021-2022, TBO
Project Management	1.0	8/2018-1/2023

MVTX labor profile in the full proposal

	Escalation + Overhead + Contingency
Labor	$2.5M
M&S	$4M ($3.75M if RU produced in FY18)



Only engineers and Technical staff costed to the project

Early funding motivation for MVTX FY18,FY19

- Buy 84 good staves from CERN following ALICE production, end FY18
  - Includes: sensors, space frame, FPC, assembly and tests
  - Very low technical risk
  - CERN will deliver 100% working staves

- Buy 58 Readout Units with the ALICE production in FY18 (was FY19)
  - FPGA chips and GBT chips as part of the ALICE production
    - GBT not commercially available product
  - ~50% cost saving w.r.t. to estimated budget (exact number confirmed 04/18)

- MVTX telescope Fermilab test beam confirmed the readout chain and sensor performance in early March 2018
  - Sensors(ALPIDE) + RU(frontend) + FELIX(backend) + sPHENIX RCDAQ

- To attract external funding & support for MVTX
  - Foreign consortium, individual institution

M&S cost options & risks

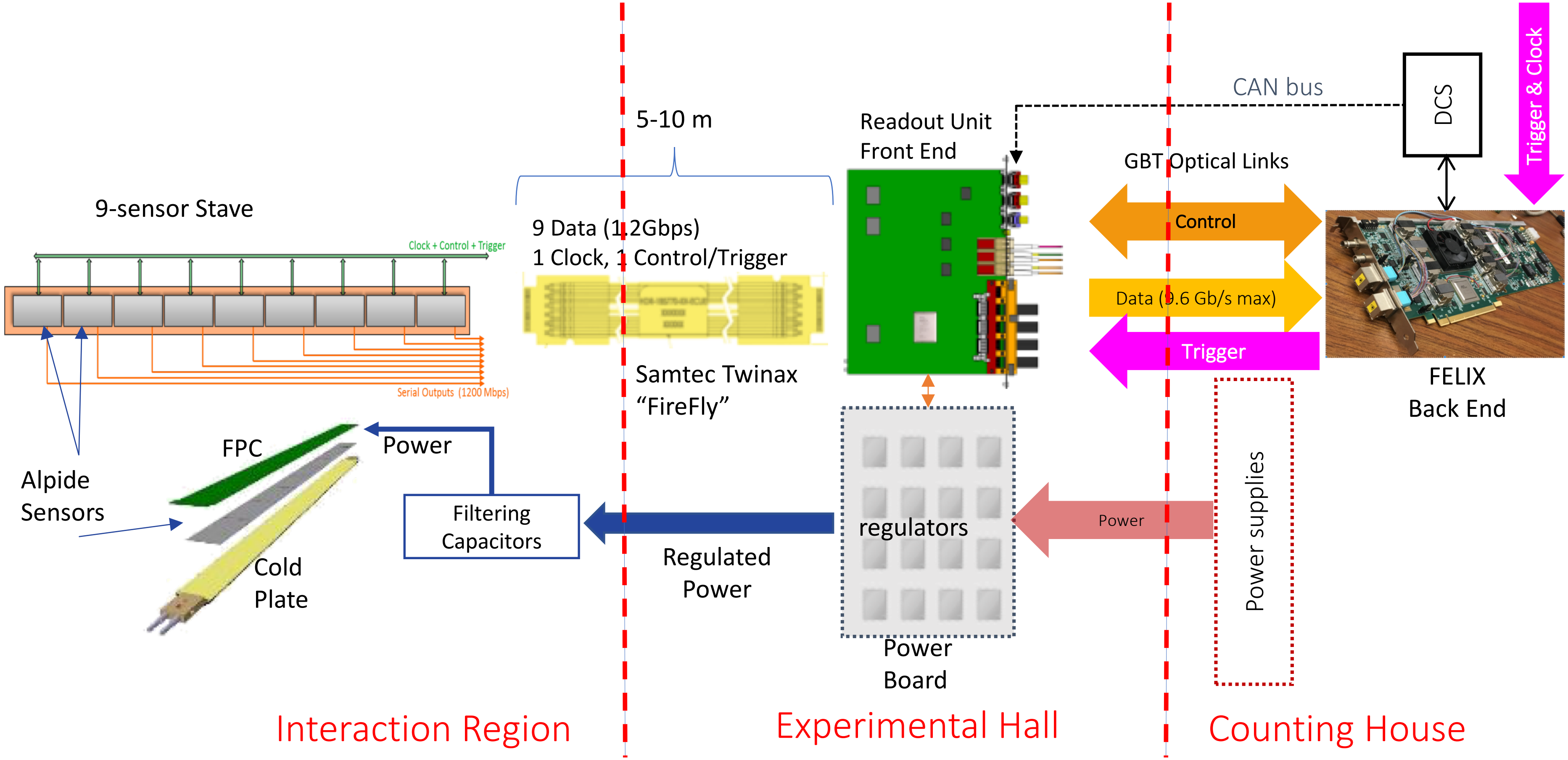
Green: low risk / MVTX baseline budget

Red: High technical risk, low cost saving or increased cost

- Staves:
  - Oprion1: MVTX production following ALICE production at CERN, ~Aug 2018
    - All material included and 100% working staves delivered
  - Option2: Stave assembly at CCNU (China)
    - MVTX project would still need to buy sensors, Flexible Printed Circuit (FPC) and space frames
    - Wuhan could assembly sensor and FPC; assembly with space frame may be done elsewhere
    - No experience assembly inner barrel → training required and hardware modified
    - Potential saving on some labor assembly work
    - Yield unknown -> schedule and cost uncertainty
- Readout Units (radiation hard electronics):
  - Option1: Produce with ALICE batch (FPGA & GBT chips) in FY18
    - 50% cost reduction w.r.t. budgeted cost
  - Option2: MVTX produces its own batches→ cost increase/double and schedule impact
- Carbon structures:
  - Exploring cost-saving options, build carbon structures elsewhere (France, Italy, Korea, China?) instead of LBNL etc.
- Reuse hardware from LDRD
  - Electronics, Power System etc.

Electronics and Controls

MVTX Electronics Overview

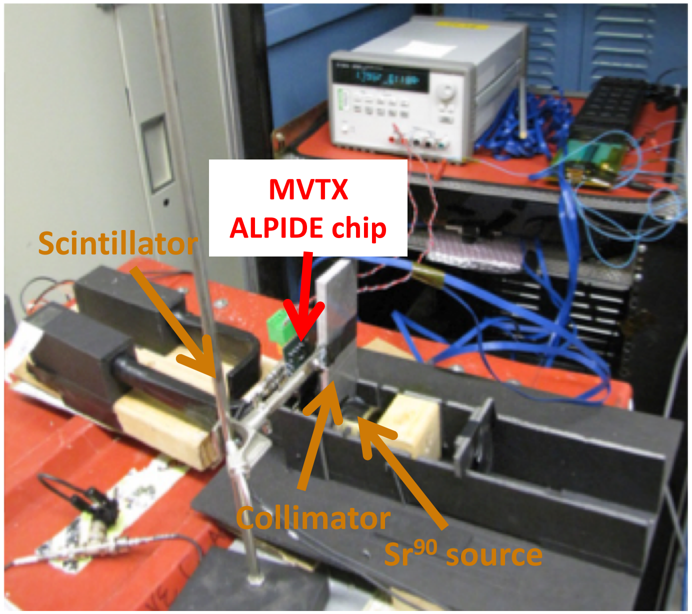


MVTX Detector Electronics consists of three parts

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

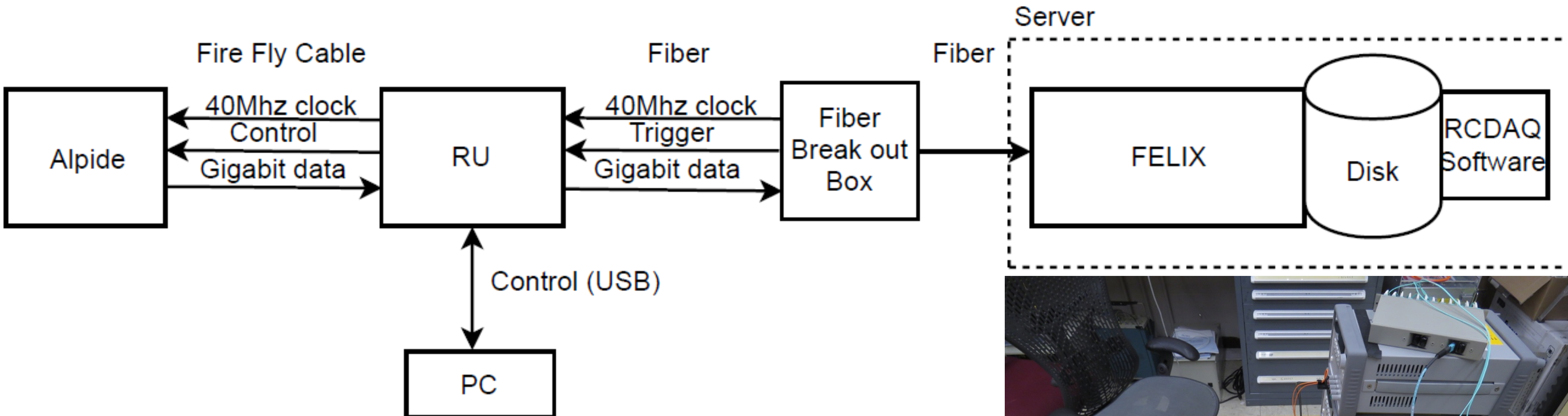
Sensor and Electronics R&D @LANL

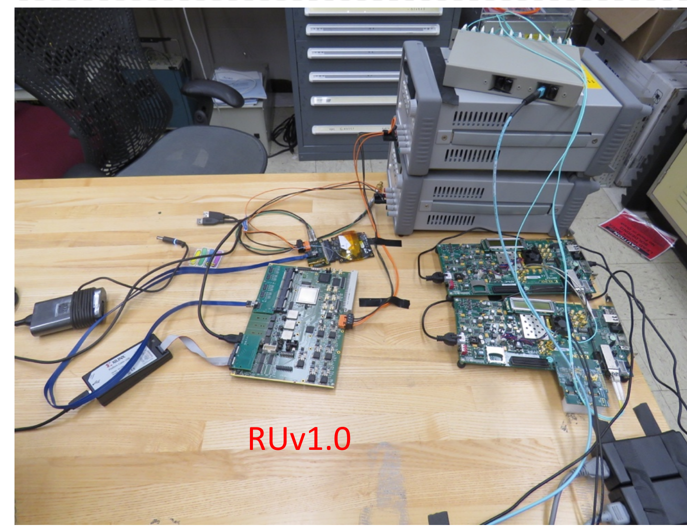
- ALPIDE evaluation and optimization
  - MOSAIC + Single Chip/Stave
  - Cosmic and source
  - Laser system
- Power unit tested
  - PU + MOSAIC
  - PU + RU
- Full readout chain demonstrated
  - ALPIDE + RUv1.0 + FELIX v1.5 + RCDAQ
  - Full stave + RUv1.x + FELIX v2.0 + RCDAQ
- Mechanical system integration
  - Conceptual design developed
  - MVTX+INTT integration



First Full Chain Readout: Success!

LANL + Martin, JohnH et al

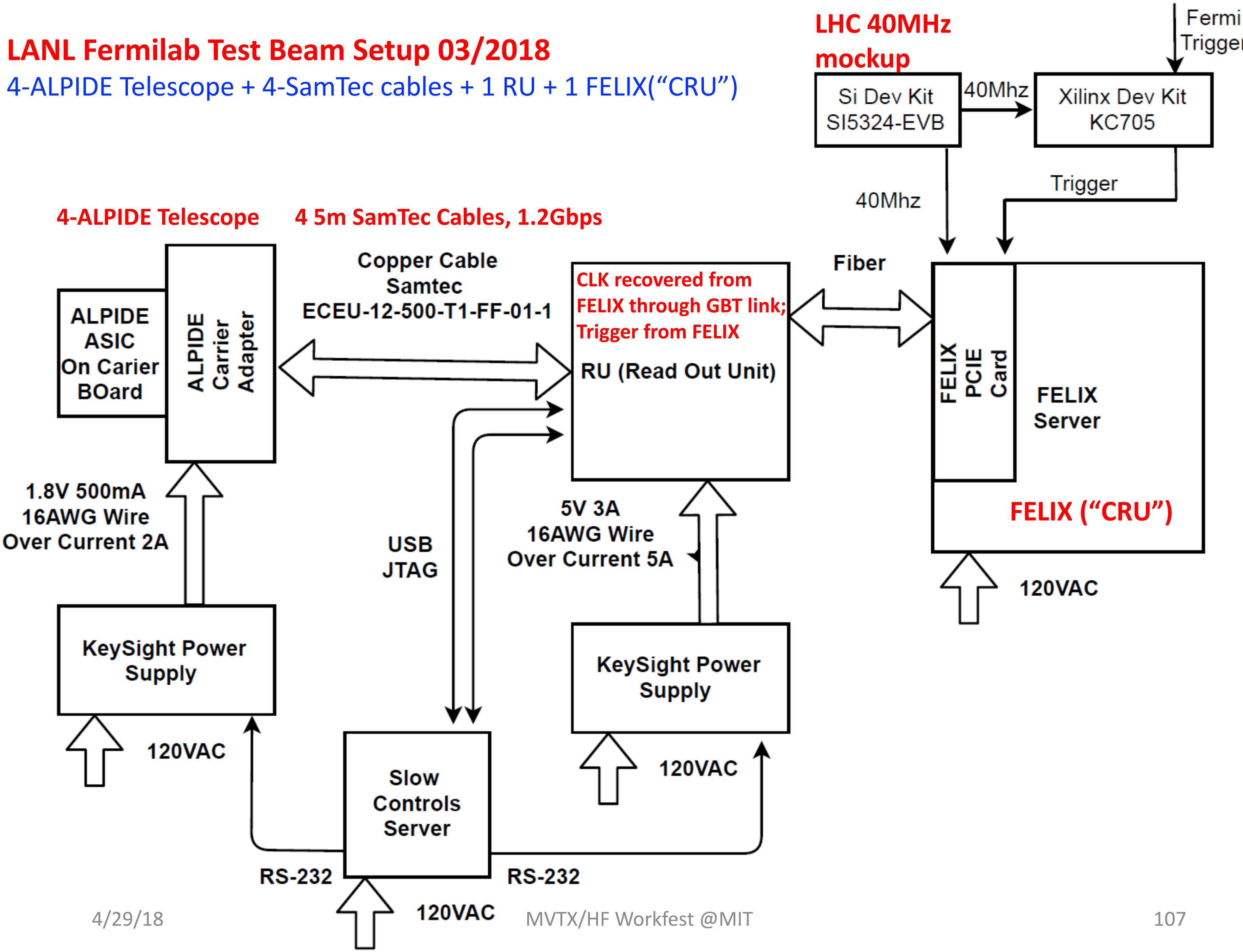




- Successfully configured, triggered and readout single ALPIDE chip
  - RU configures ALPIDE using python scripts interfacing the USB chip on RU
  - Felix distributes clock to RU, the RU then distributes the clock to the ALPIDE
  - ALPIDE is triggered on the control line, sends data at 1.2Ghz over copper
  - The RU receives the data and sends the data to FELIX over fiber using GBT link
  - FELIX packs the data and stores in on disk which is read out using RCDAQ
  - Configured ALPIDE to accept triggers from FELIX using python software that came with the RU
  - Configured GBT link to recover clock from FELIX and GT link (FGPA gigabit interface)
  - 8 RU's emulated using 1 fiber link per RU on FELIX, 15kHz, 400 hits per RU
- Currently working the implementation of the above using a Stave

LANL Fermilab Test Beam Setup 03/2018

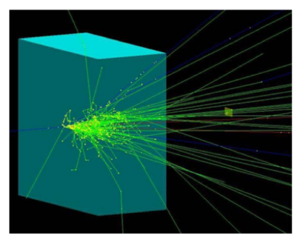
4-ALPIDE Telescope + 4-SamTec cables + 1 RU + 1 FELIX(“CRU”)

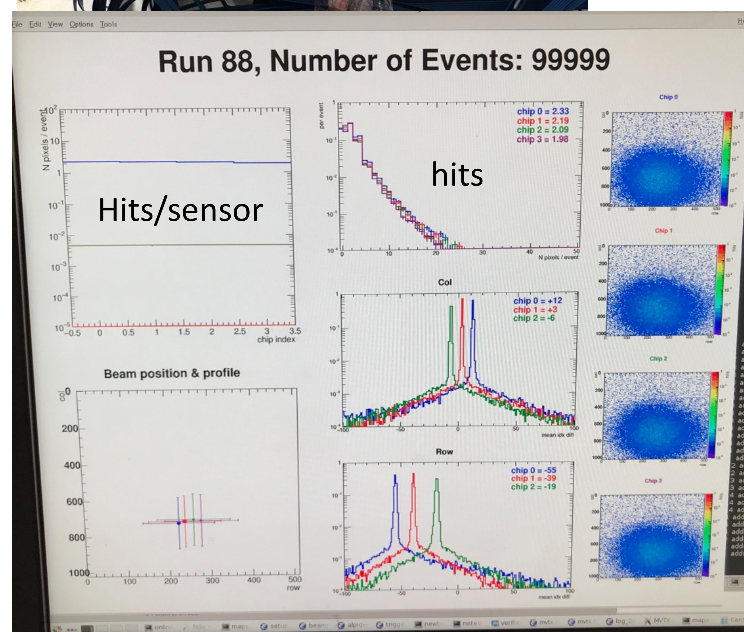


Achieved all goals and more!

- Tested a new readout scheme
  - 4 sensors (~3 “staves”+1 Chip) per RU
    - ALICE: 1 stave per RU for IB
- Sensor performance evaluation
  - Cluster size
  - Threshold, signal shaping, trigger delay
- System stress test
  - High multiplicity events created via lead bricks “shower”
  - With 5, 10, 20cm lead bricks
- Analysis software developed
  - Online monitor
    - hit distribution, relative alignment etc.
  - Offline reconstruction, alignment etc.
    - Preliminary alignment, ~O(100um)

4 sensors
Connected
to one RU



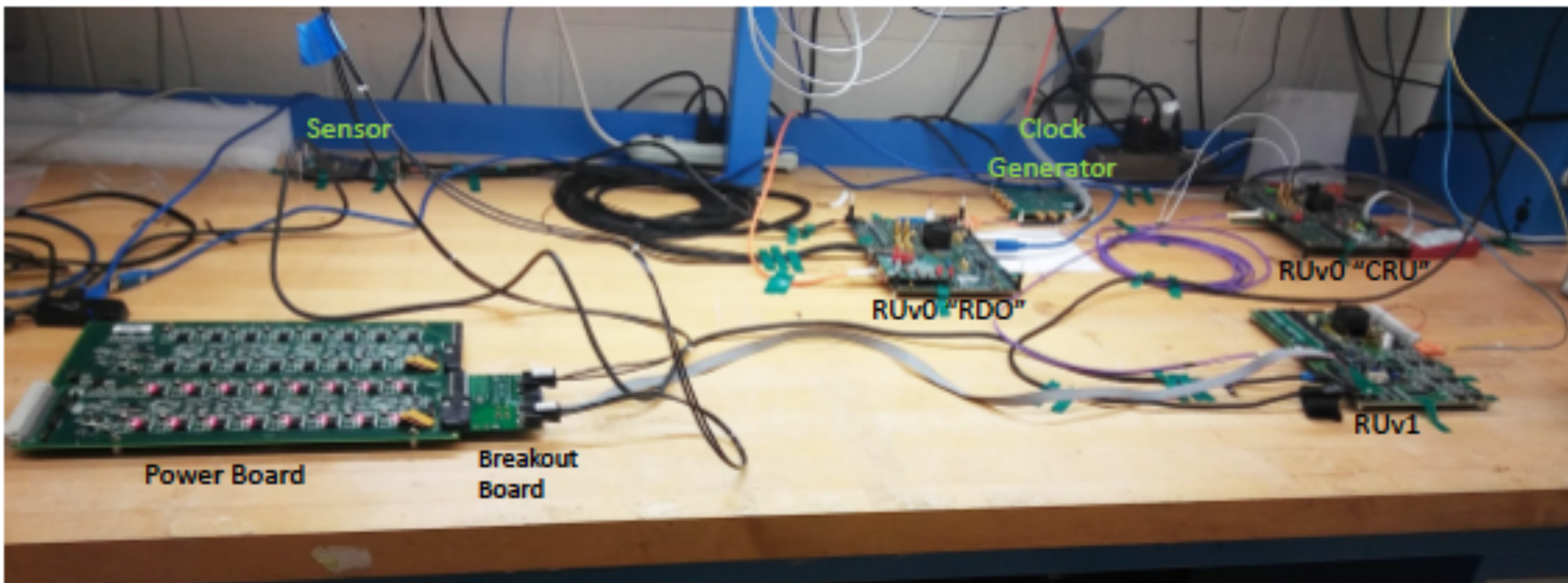


Parallel Effort at UT-Austin – Shared R&D

Test Setup at UT Austin

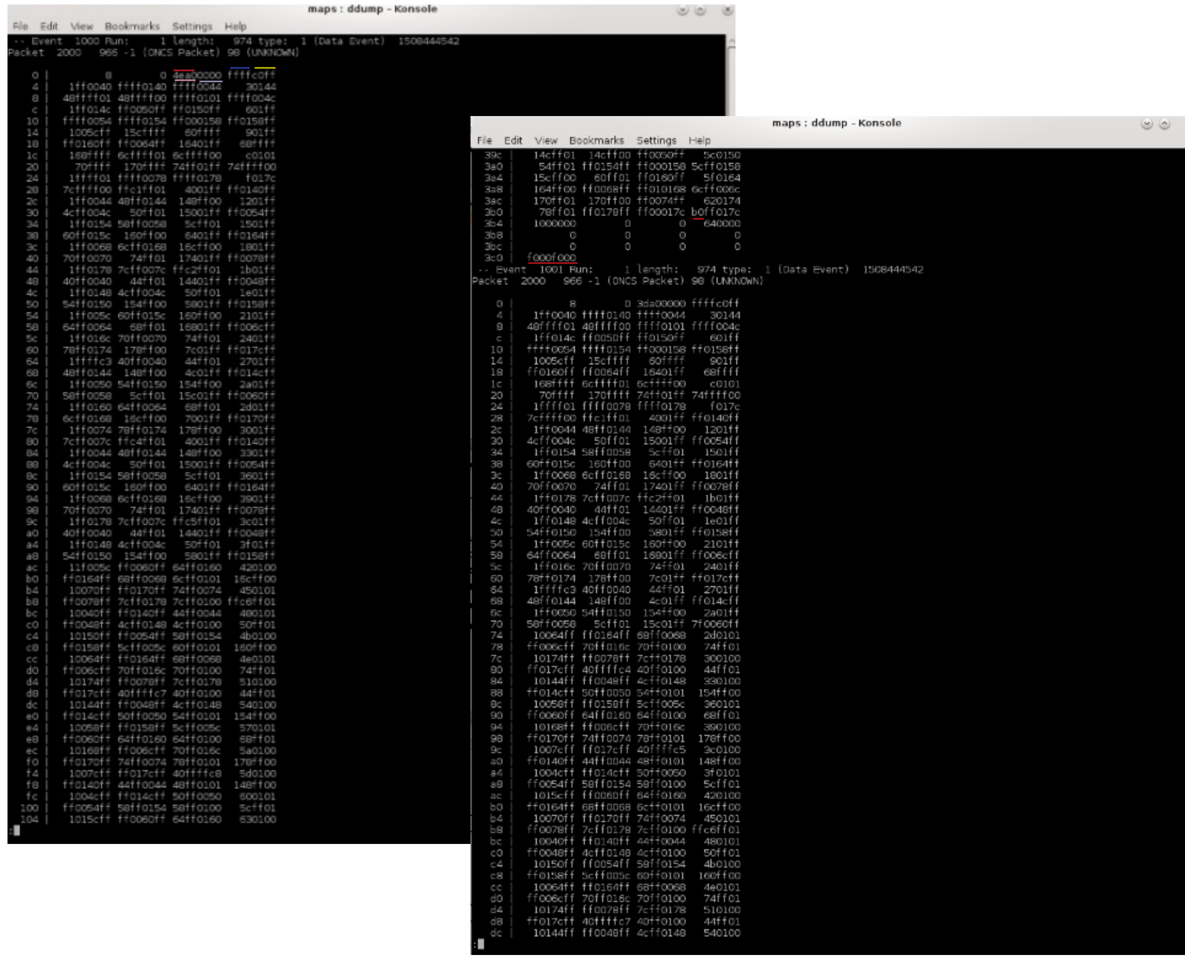
ALICE ITS UPGRADE

- RUv1 with transition bd + power mezz
- RUv0 as CRU emulator
- Single sensor on chip carrier board with interface board (only usable for IB tests, wrong pins for OB)
- Long (5m) FireFly cables
- Power board with single breakout board
- Now also tested with 9-sensor Inner Barrel module



RC DAQ event Data Screen Shot

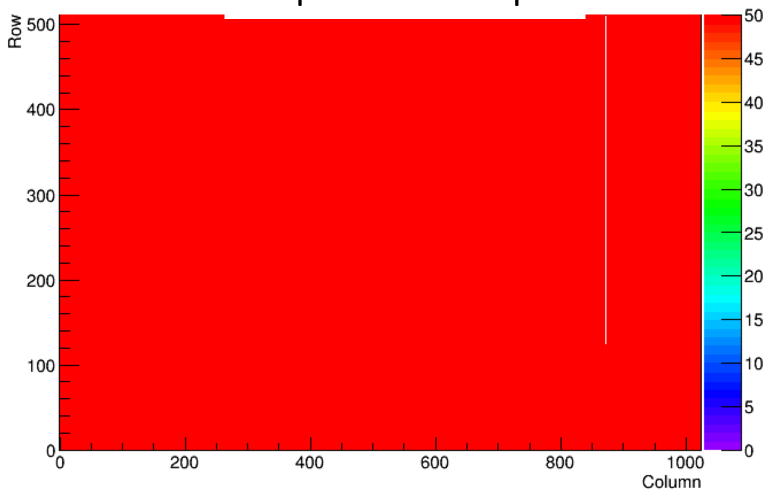
- Rcdaq receiving events from FELIX using ddump utility
- ffff0044ffffc0ff4ea0
- a0 - Chip Header
- 4e - bunch counter
- ff - IDLE
- c0 - Region Header
- 40 00 - first Hit
- Second screen shot showing end of one event (b0…, f000f000) and the beginning of another



LANL R&D: Single ALPIDE Chip Scan – Active Channel Fraction

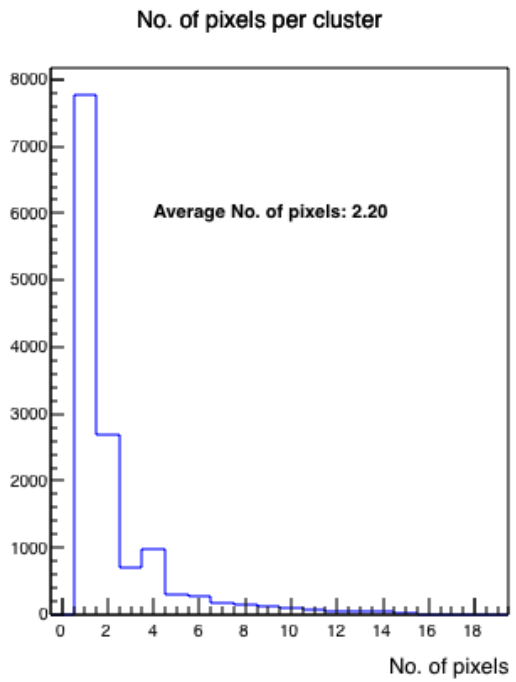
- Scanned the available chips and stave at the LANL lab through digital scan to verify the dead channel fraction: the bad channel fraction is <1%.
- Similar results with different readout speeds.

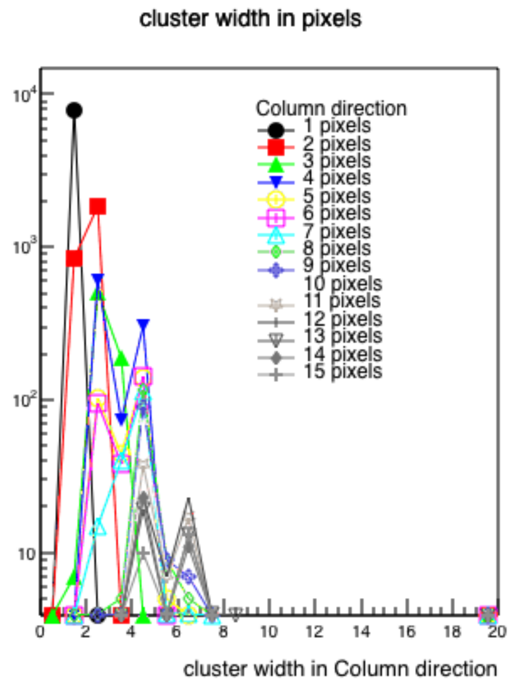
Chip 1 test example

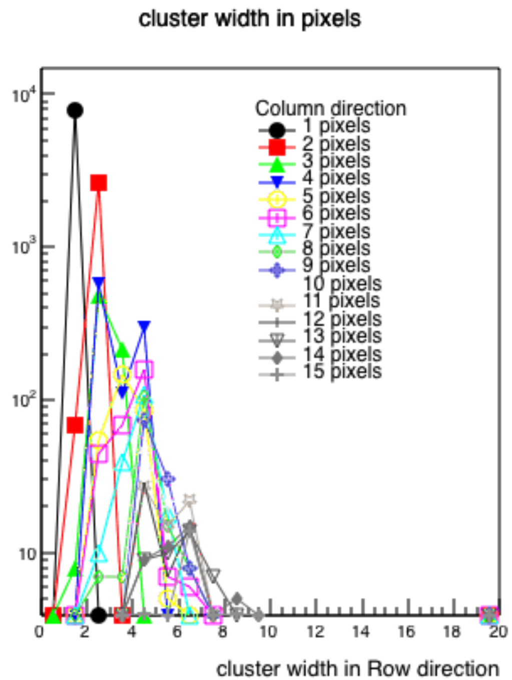


No. of 0 hits	Cold channel	Hot channel	Bad fraction
777	1	0	0.15%

Hit Pixel Cluster Distribution from Source Test (Sr^{90})







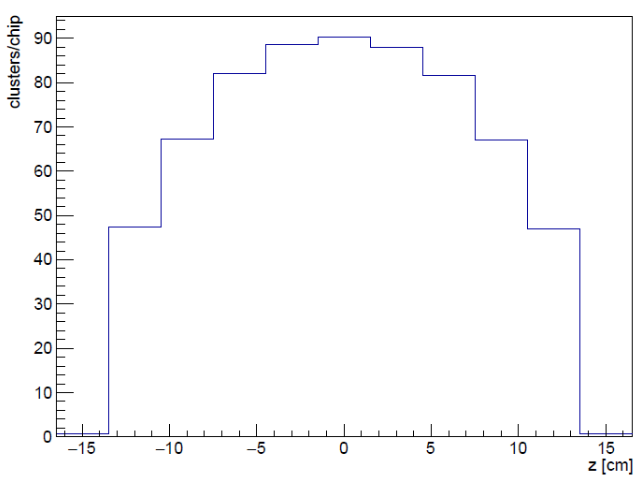
Data Rate Calculations

	Collision Rate
Au Au	200kHz
P P	10Mhz

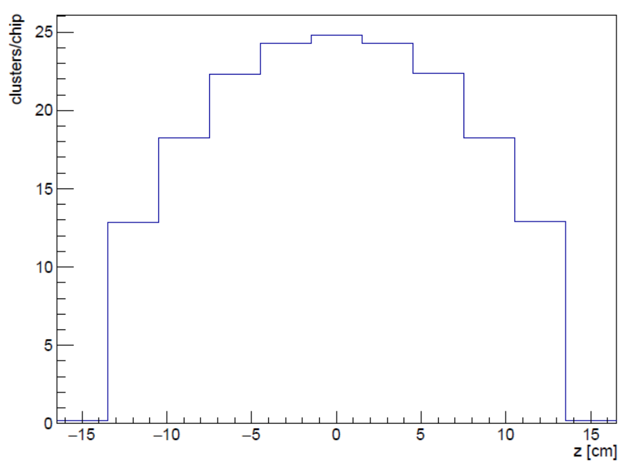
- Assume 10us window and cluster size 3

	Au Au	P P
# of collisions	**2** = 10us * 200kHz	**100** = 10us * 10Mhz
# of hits, hottest chip	**270** = 3 * 90	**75** = 3 * 25
# of hits in a stave	**1983** = 3 * 661	**543** = 3 * 181

Central Au-Au collision with 2.0 pileup MB collisions: 661 clusters/stave in layer 0



p-p collision with 100.0 pileup collisions: 181 clusters/stave in layer 0



Expected Data Rate (from the proposal)

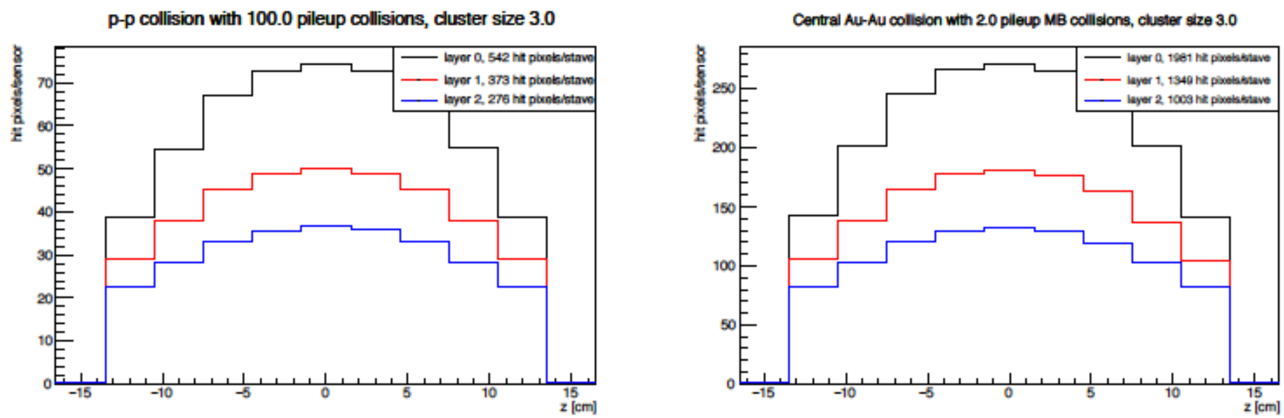


Figure 9: Average hit occupancy per event. Conservative assumptions are made regarding integration time (10 μs) and cluster size (3 pixels/cluster). In addition, the pileup collisions are assumed to occur inside the MVTX acceptance ($|Z_{Vertex}| < 10$ cm) when in fact they will be widely distributed along the beam axis.

The highest occupancies are expected in layer 0, at $\eta = 0$, with central Au+Au collisions. Figure 9 shows that MVTX sensors average 271 hit pixels/event, for an occupancy of 0.052%. Lab tests (further described in Section A) have demonstrated successful MVTX readout at larger hit occupancies.

Noise < 10^-5
@Fermilab test bean

~30 Gb/s max.

	10^{-4} noise	Hit occupancy only		Hit + noise occupancy	
	occupancy	p+p [MB/s]	Au+Au [MB/s]	p+p [MB/s]	Au+Au [MB/s]
L0 FEM	26	29	107	55	133
DAM	219	173	630	392	848
MVTX	1305	1041	3781	2346	5089

Table 2: Raw (uncompressed) data rates based on a worst-case noise occupancy of 10^{-4}, the hit occupancies of Fig. 9 at 15 kHz trigger rates, and the sum of the hit and noise.

Project Organization

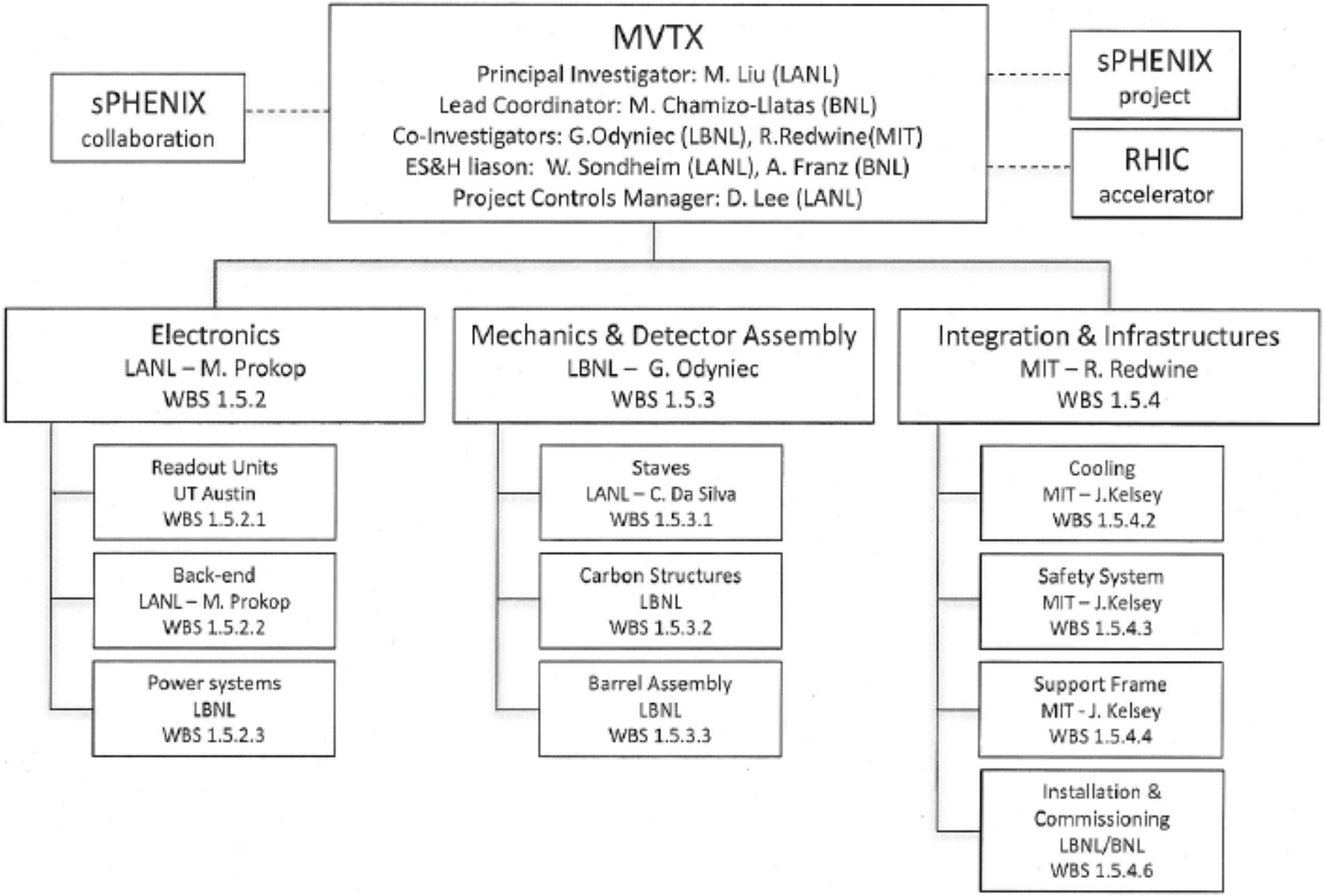


Figure 40: Organization chart of the MVTX project.