MVTX Status & Plan

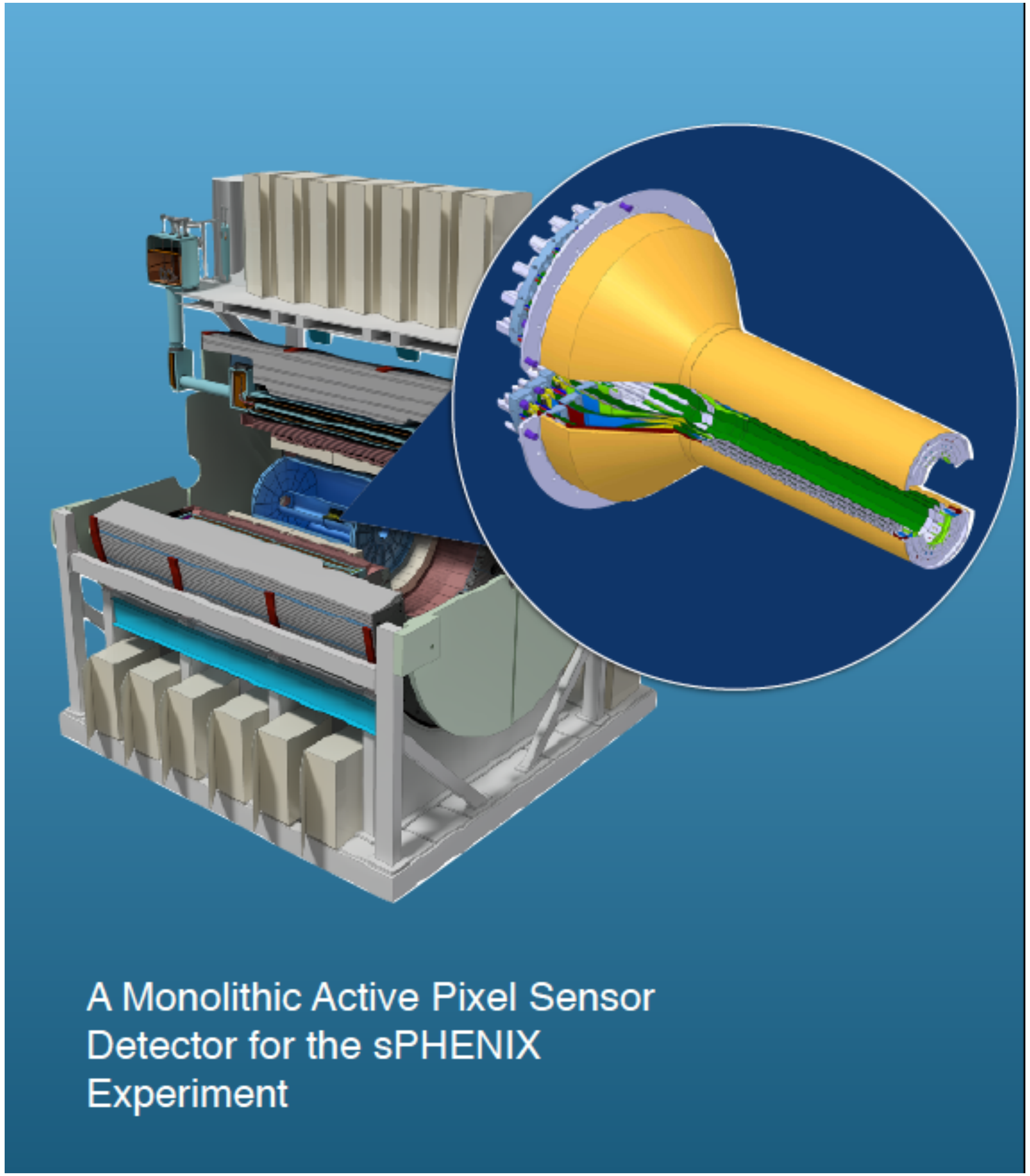
Ming Liu
Los Alamos National Lab
For the MVTX Group

sPHENIX Collaboration Meeting, Santa Fe, NM

Outline

- MVTX workfest summary
    - Plan for DOE submission

- Project status and plan
    - Physics and Simulations
    - Readout and Controls
    - Mechanical Integration
    - Budget and Schedule

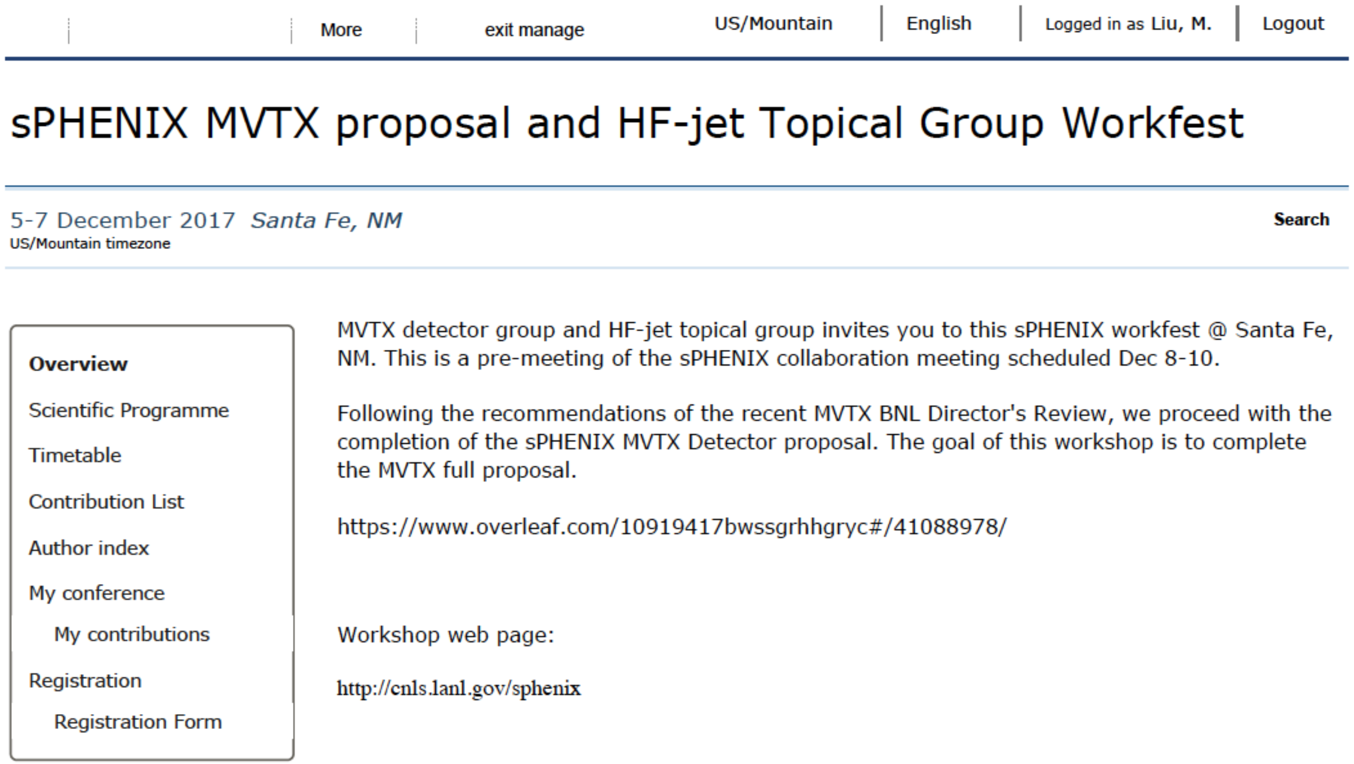


MVTX & HF-Jet Workfest @Santa Fe,12/5-7, 2018

- Goal - complete full proposal, implement recommendations from last Director's Review
  - Expand the MVTX Science case
  - Update cost & schedule

- About 25 participants

- 4 working groups
  - Physics and simulations
  - Sensors and readout
  - Mechanical system
  - Budget and schedule



Updated the proposal with latest results & development!
https://www.overleaf.com/10919417bwssgrhhgryc#/41088600/

On track for DOE submission in late January 2018

4 Working Groups

23 institutions, and counting!

- ***Physics and Simulations***
  - HF-Jet TG, Jin, Xin, Tony, Chris, Sanghoon, Haiwang, Darren, Xiaolong, SukHyun, Cesar, Ming, Nu et al
- ***Staves, electronics & power system***
  - Readout - Mark, Sho, AlexT, Jo, Kun, Ming, Giacomo, Kai/BNL/ATLAS, Jin, Martin, JohnH, Eric …
  - Staves/Sensors- Cesar, Xuan, Maria, Ming …
- **Mechanical system & Integration**
  - Integration - Bob, Grazyna, Walt, Jim K., Giacomo, Chris O'…
  - Carbon structures – Grazyna
- ***Project Cost, Schedule, Risks***
  - Dave, Maria, Ming, Bob, Grazyna, Giacomo, Jo, …

* Working group team leaders

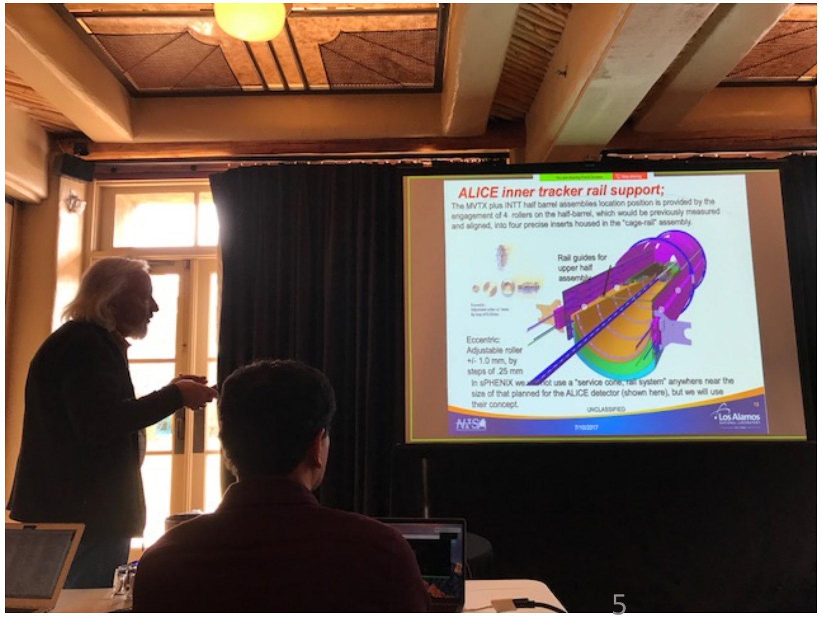
A Monolithic-Active-Pixel-Sensor-based Vertex Detector (MVTX) for the sPHENIX Experiment at RHIC

A proposal submitted to the DOE Office of Science
January 18, 2018

DOE Office of Science Program Manager: Dr. Jehanne Gillo

Proposing Organization:	Los Alamos National Laboratory
Collaborating Institutions:	Brookhaven National Laboratory Lawrence Berkeley National Laboratory Massachusetts Institute of Technology Univ. of California at Berkeley Univ. of California at Los Angeles Univ. of California at Riverside Charles University (Czech) Central China Normal University (China) Univ. of Colorado Czech Technical University (Czech) Florida State University Georgia State University Iowa State University National Central University (Taiwan)* Univ. of New Mexico New Mexico State University Purdue University Univ. of Science and Technology of China (China)* Sun Yat-Sen University (China)* Univ. of Texas at Austin Yonsei University (Korea) RIKEN/RBRC (Japan)

Very productive workfest



MVTX Full Proposal in Progress
- all key elements discussed and updated/to be updated soon

Table of Contents

63 pages now … will be updated through out next a few weeks

Plan for the Proposal Submission – Draft Timeline

on-going discussion with ALD about the submission date and process

- Draft ready for sPHENIX collaboration comments:
  - Jan 3(Wed)-10(Wed), 2018, one week
  - Update document – 1/11(Thur)-15(Mon), 2018

- For ALD review and feedback
  - Jan 15(Mon)-22(Mon), 2018

- Ready for DOE submission
  - Jan 22(Mon)-29(Mon), 2018, final editing, one week
  - Jan 29(Mon), 2018, ready for submission

- To be submitted before Feb 2018 DOE budget meetings
  - 2/22/2018 for LANL NP, similar timeframe for BNL and LBNL

MVTX Project Status and Highlights

- Expanded science
- Sensor & readout system
- Mechanical system
- Budget & Schedule

Xin's talk

Money Plots Updated: R_AA and V_2

B-meson B-Jet

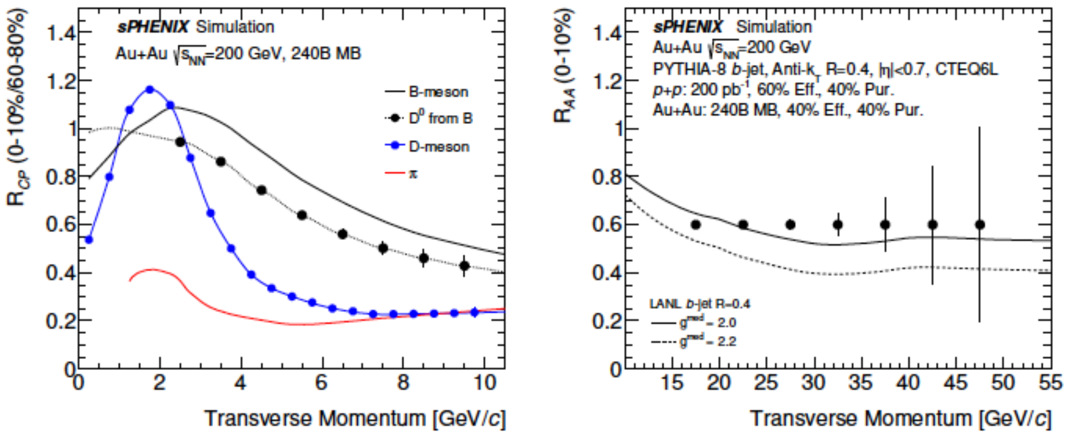


Figure 1: Projected statistical uncertainties of R_{CP}/R_{AA} measurements of non-prompt/prompt D^0 mesons and b-jet as a function of p_T in 0–10% central Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV from a dataset of 240 billion minimum bias Au+Au events.

B-meson B-Jet

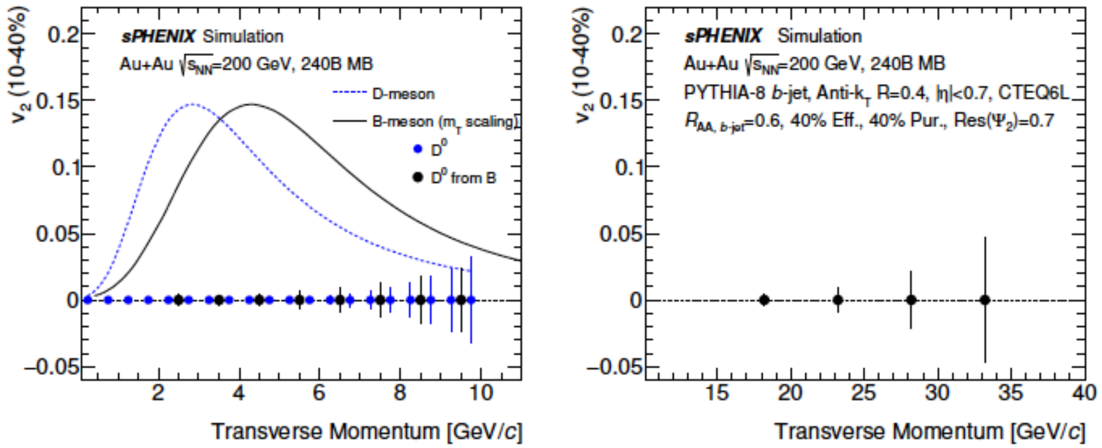
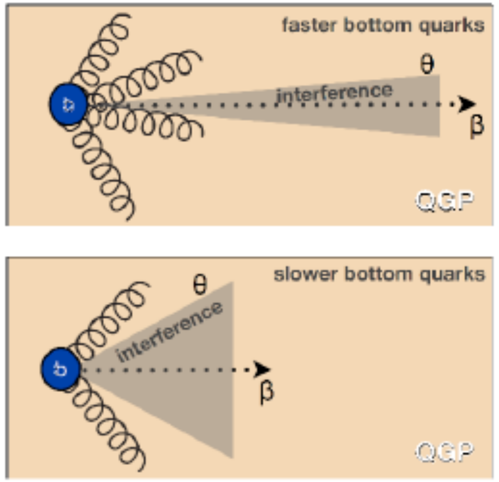
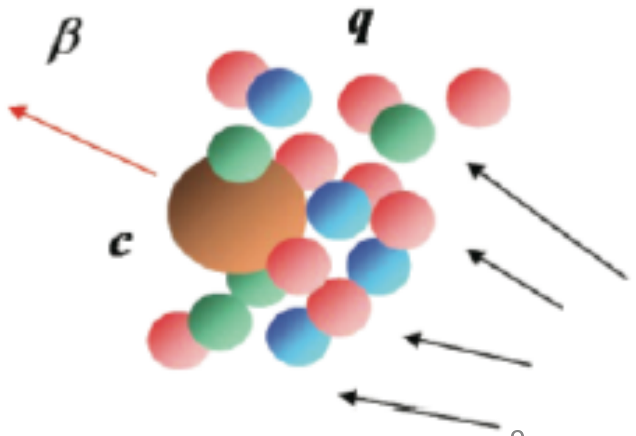


Figure 2: Projected statistical uncertainties of v_2 measurements of non-prompt/prompt D^0 mesons and b-jet as a function of p_T in 10–40% central Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV from a dataset of 240 billion minimum bias Au+Au events.



To be updated with more model calculations

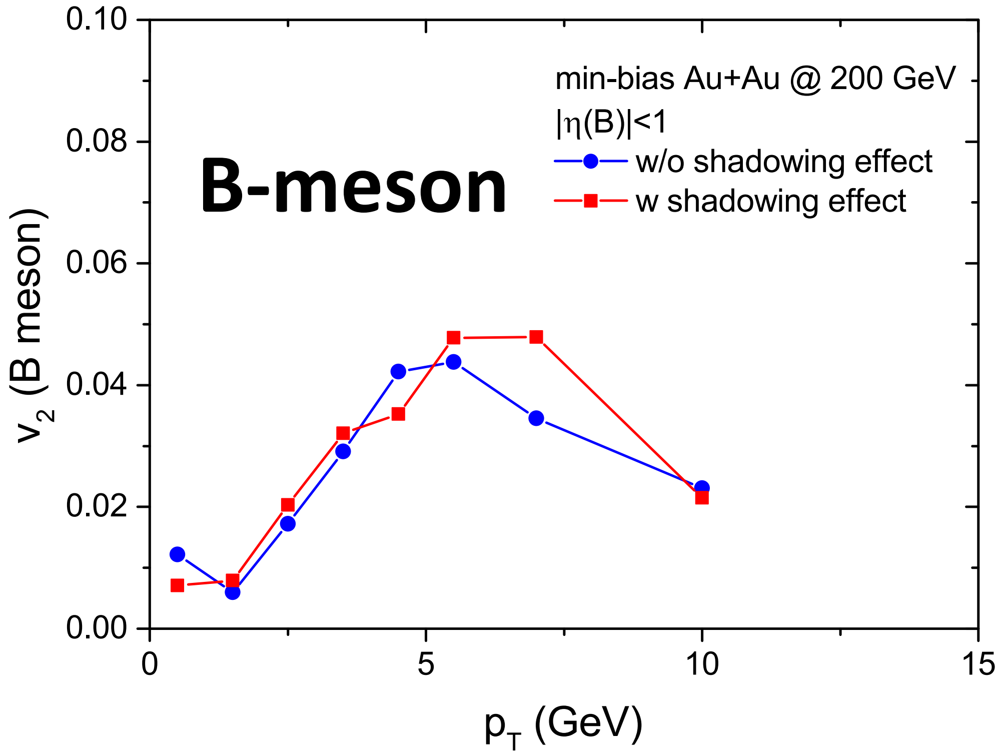


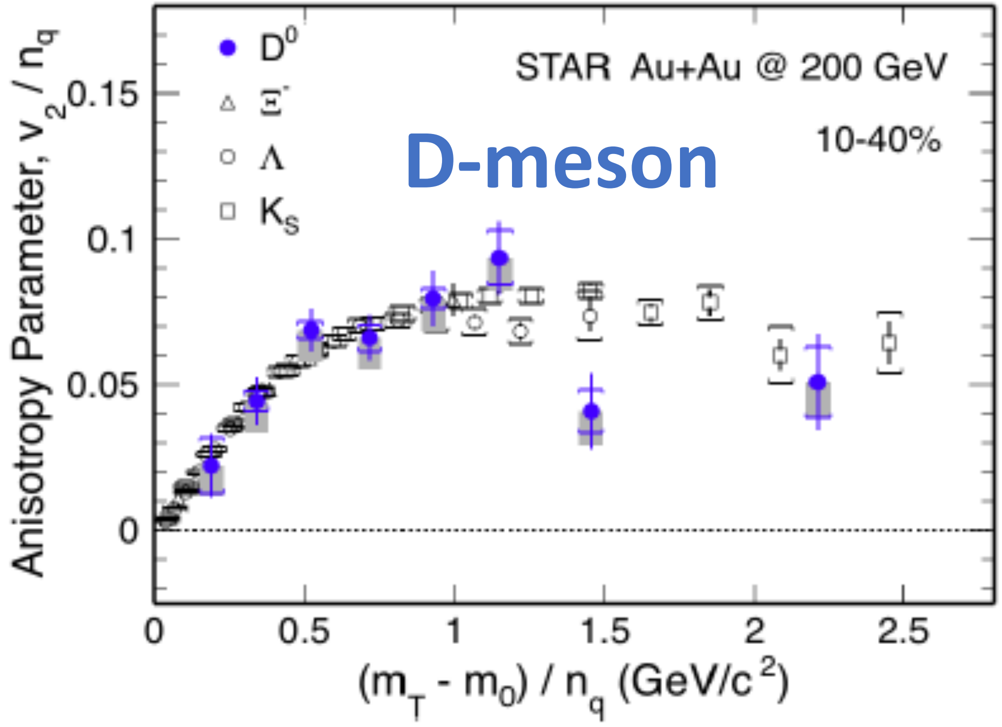
More Theoretical Inputs (I): B-meson v2

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

New calculations from PHSD for B-hadrons:

- Significant v2 suggested, but may NOT follow the scaling due to large bmass!



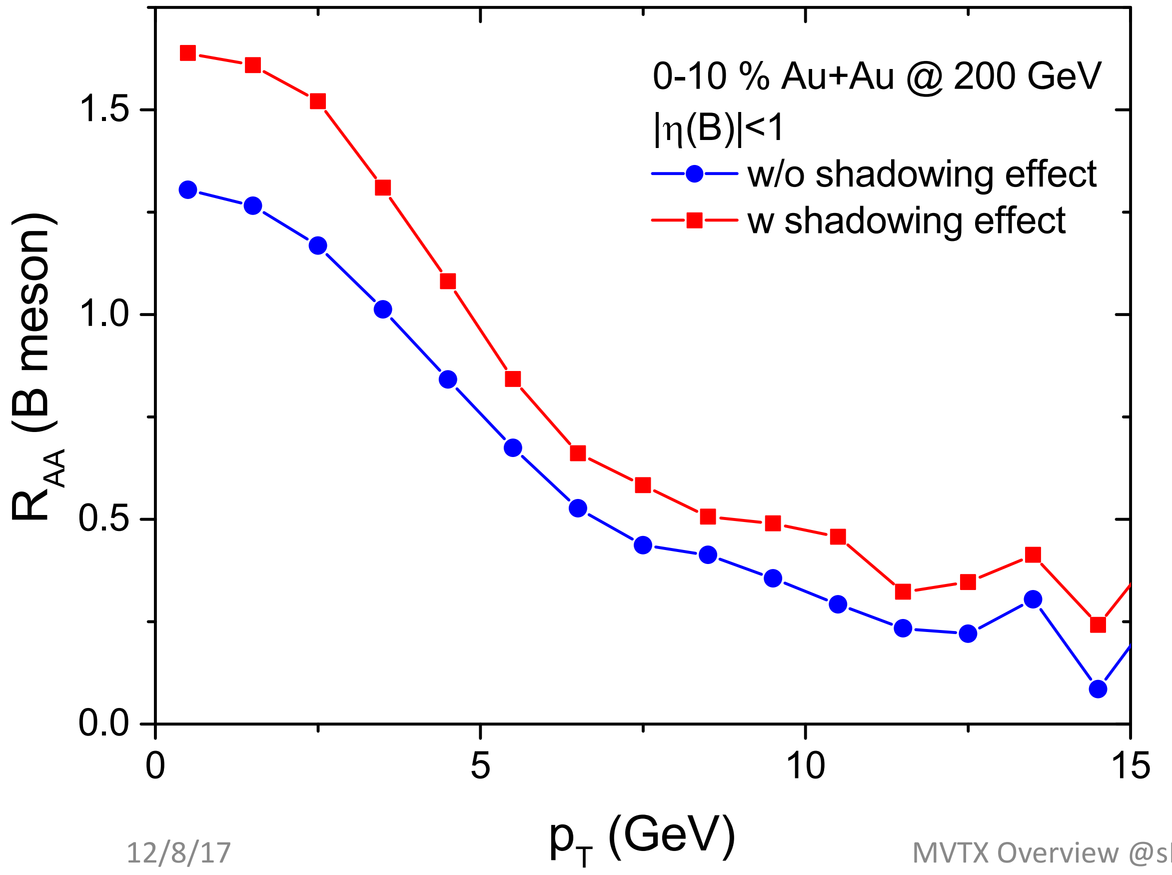


STAR, PRL 118 (2017) 212301

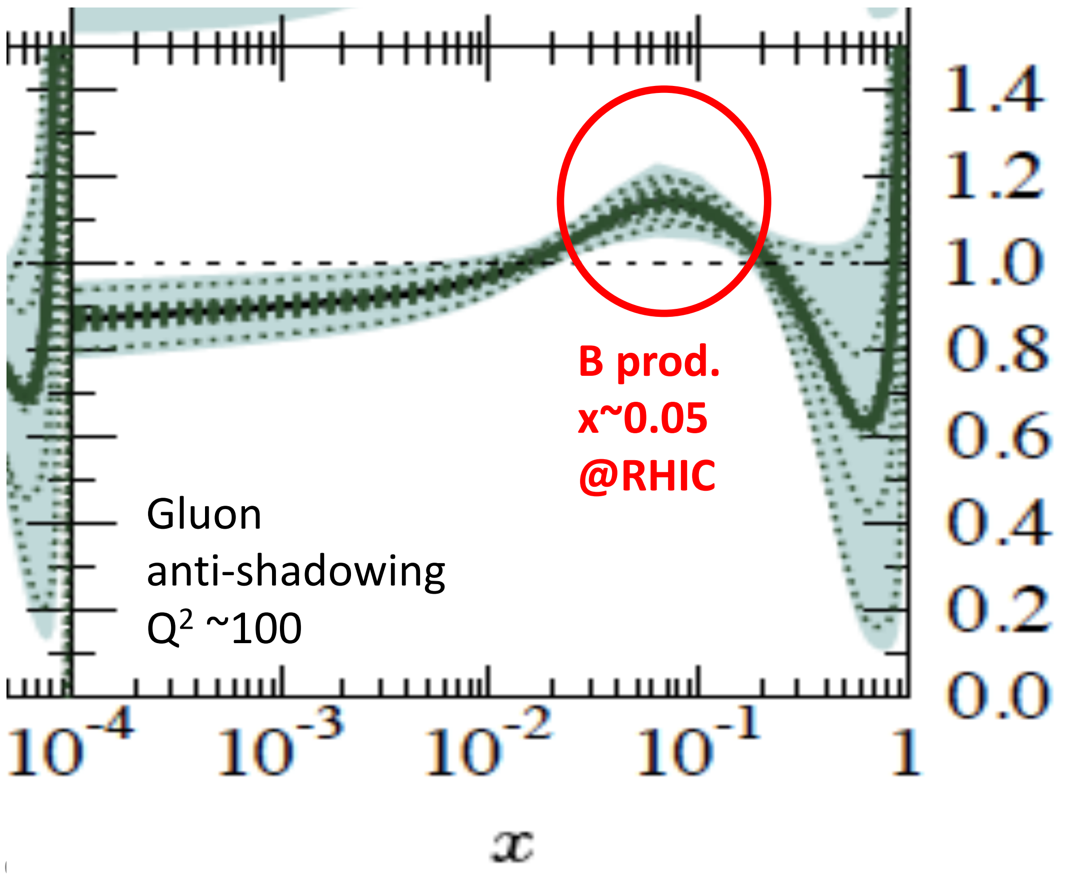
More Theoretical Inputs (II): B-meson R_AA

New calculations from PHSD for B-hadrons:

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



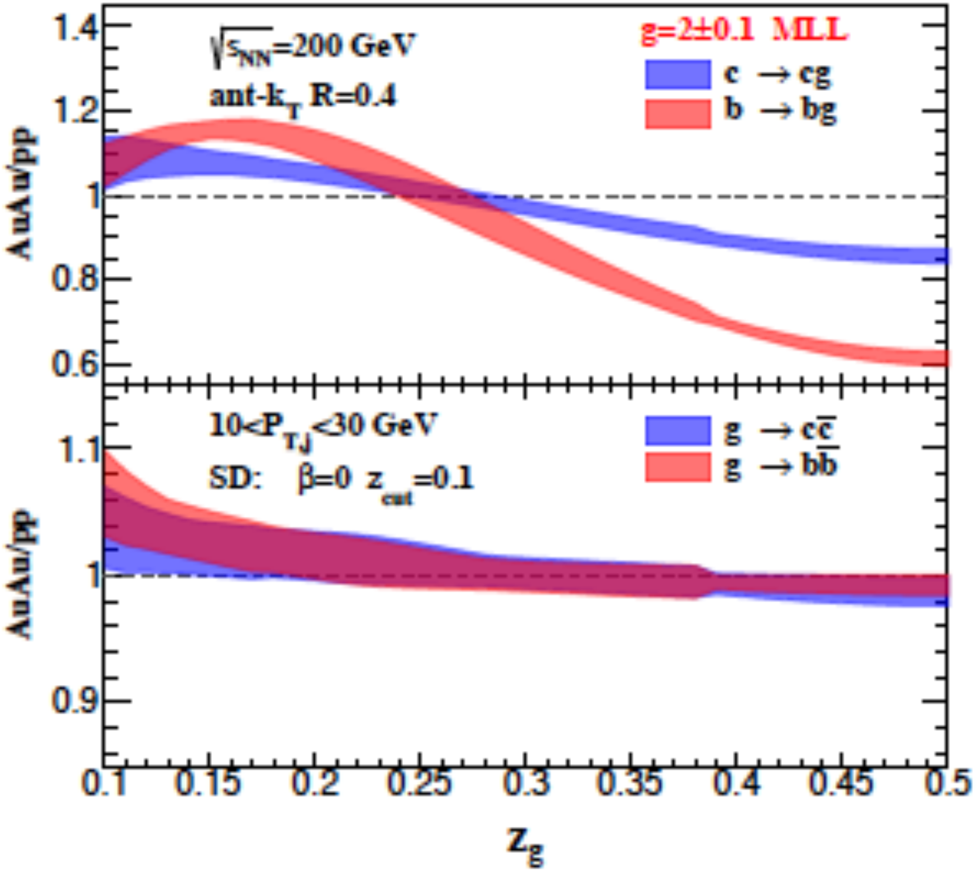
EPS09

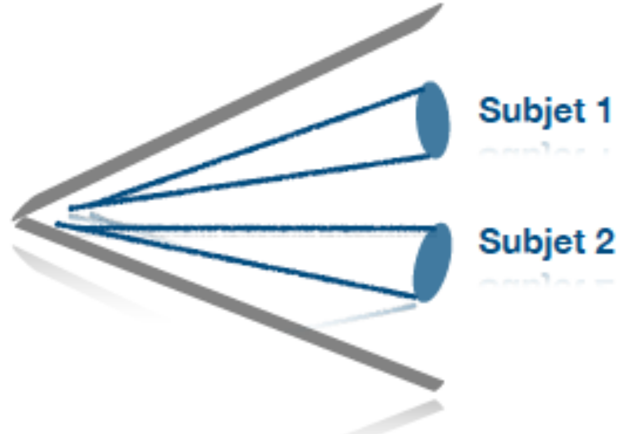


More Theoretical Inputs (III): HF-Jet Substructure

H. Li & I. Vitev @MVTX Workshop

- QCD Splitting function in QGP

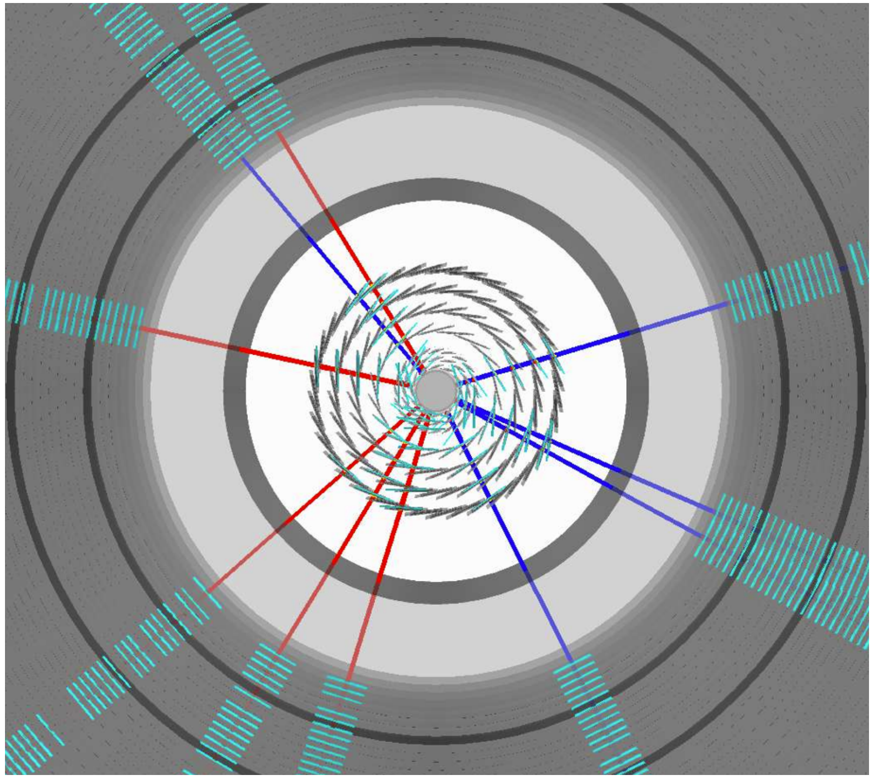




Undo last stage of C/A clustering

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

Simulation Updated

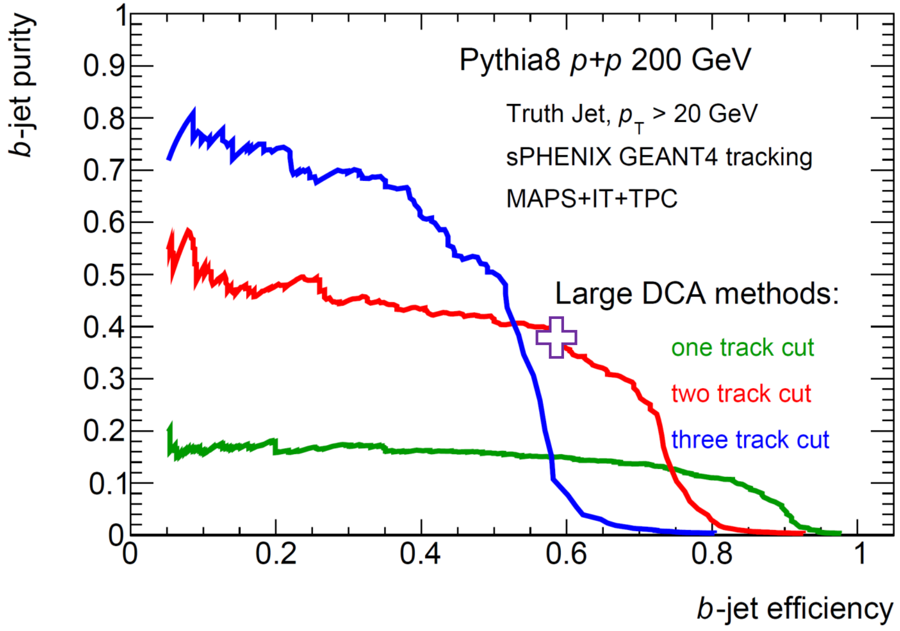


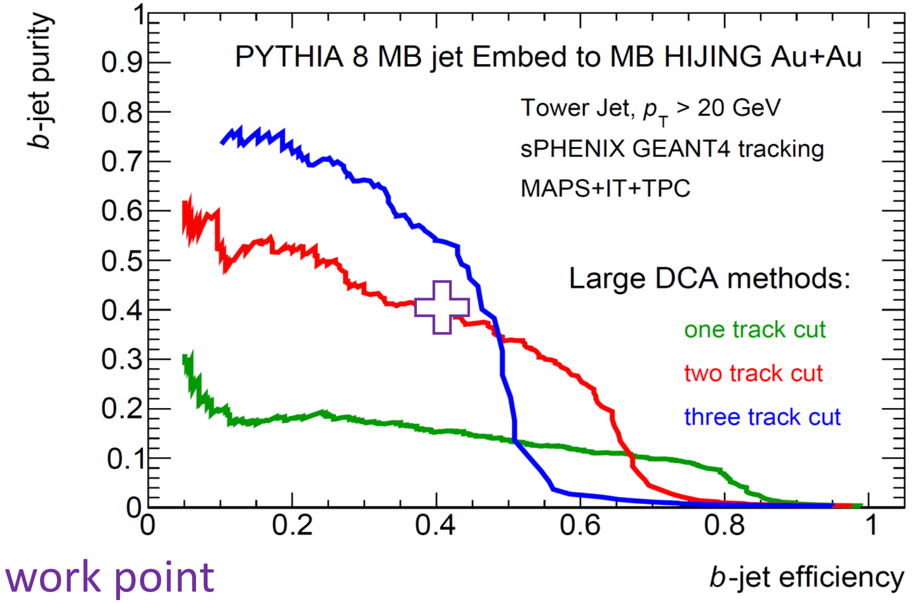
- Fully implemented MVTX models used in performance projection
- Large jets production in full detectors, including detailed MVTX detector + full calorimetry
  - 250k MB jets in p+p collisions
  - 100k MB jet embedded into central Au+Au collisions

Updated *p+p* and Au+Au *b*-jet Projections

- *b*-jet tagging projection re-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

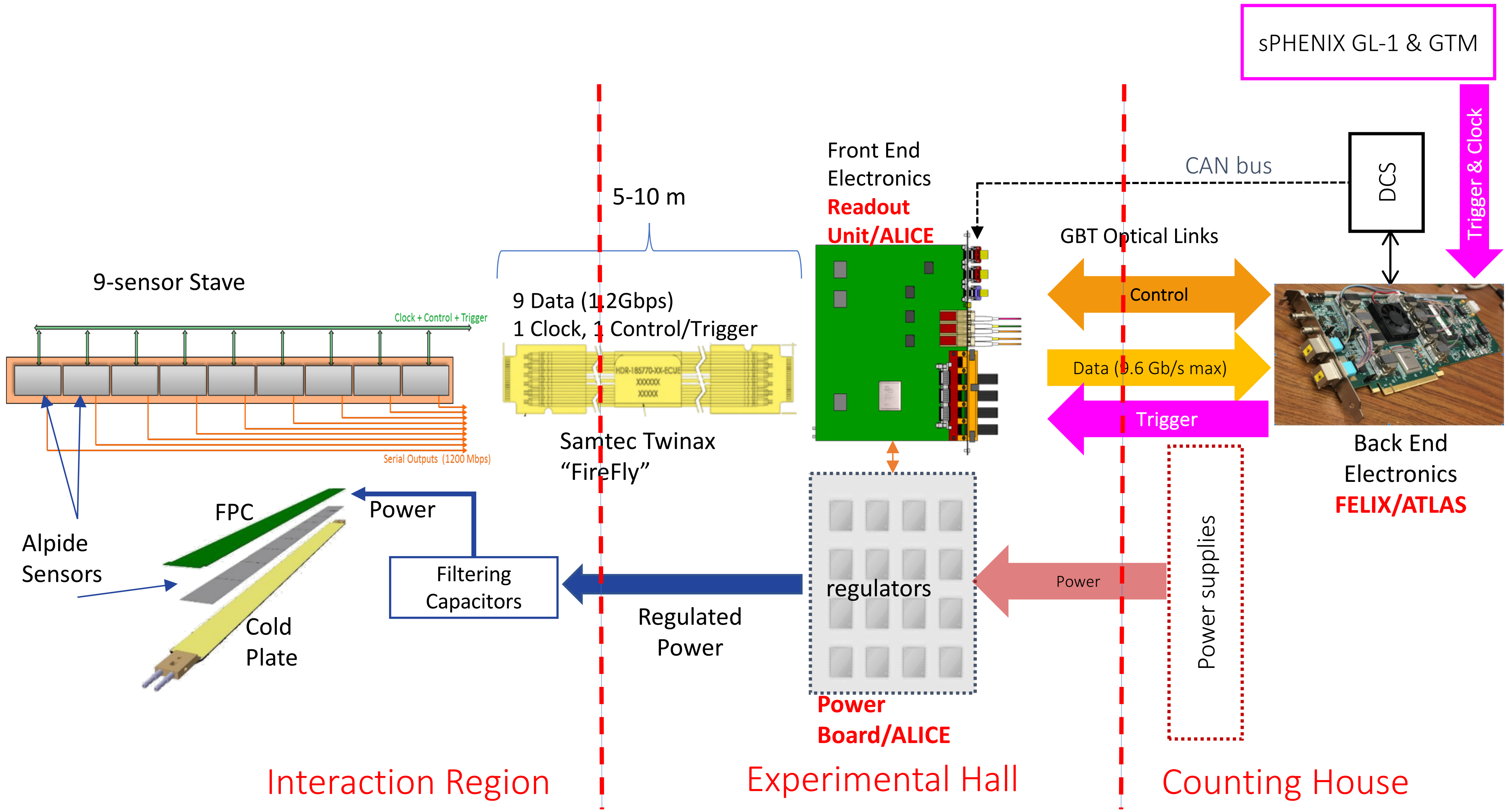




sPHENIX b-jet work point

Sho, Alex & Xuan's talks

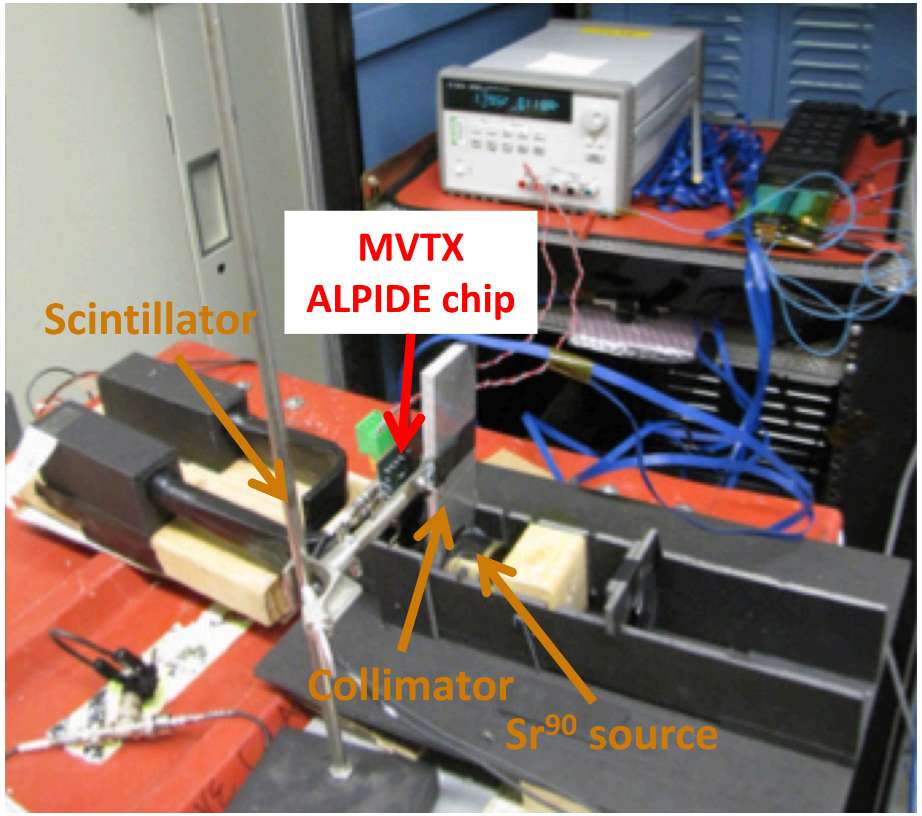
MVTX Readout and Control R&D



Excellent Progress in LANL LDRD

- 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

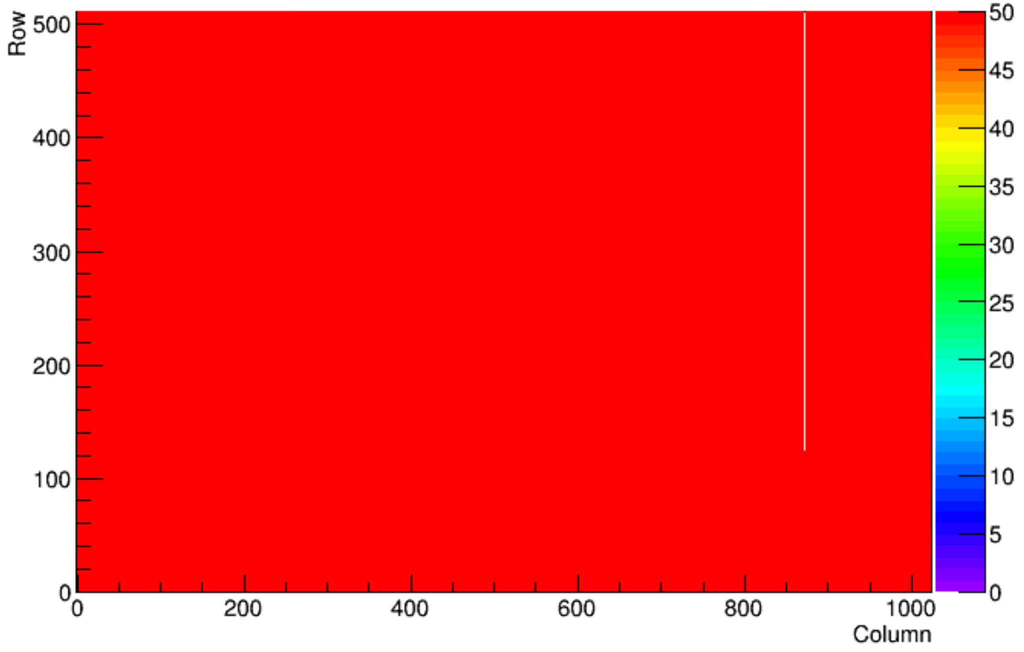
- A telescope under development
  - Mechanical frame, cooling etc
  - GEANT sim, alignment & tracking



Single ALPIDE Chip Scan – Active Channel Fraction

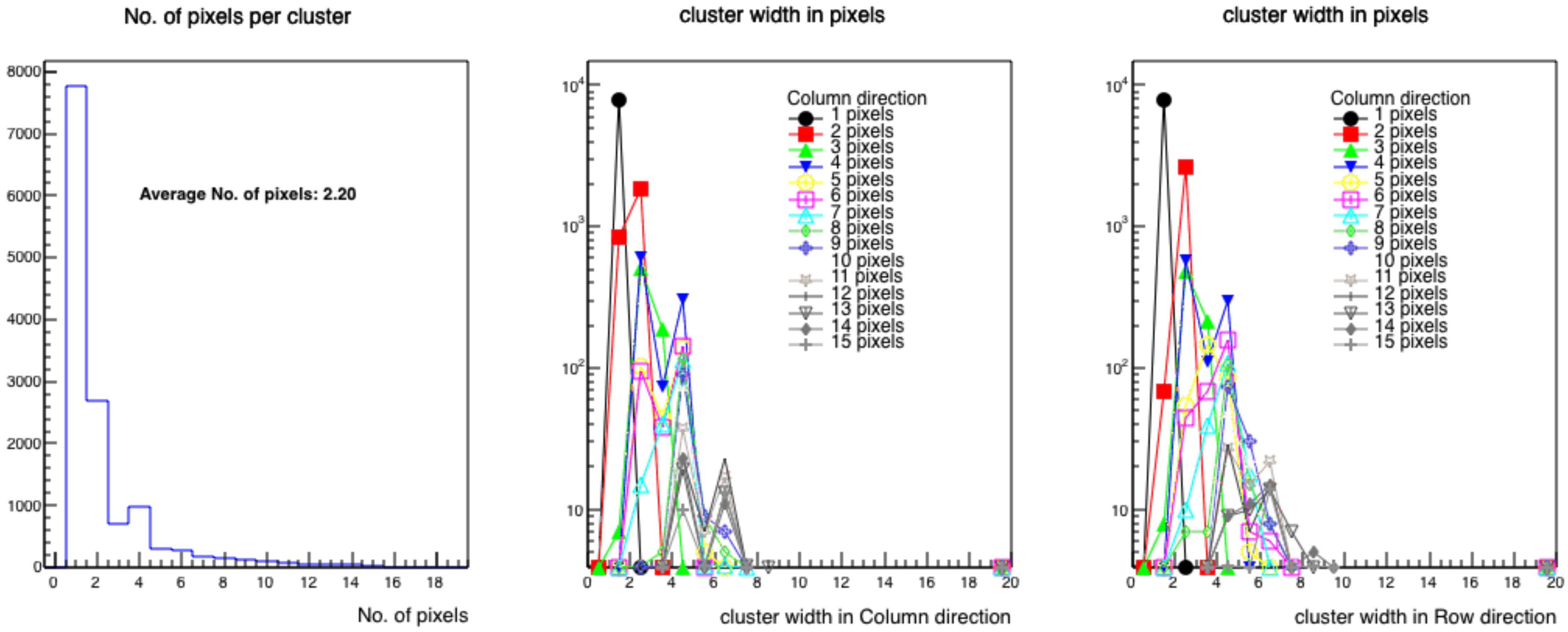
- Scanned the available chips and stave at the LANL lab through digital scan to verify the dead channel fraction: the bad channel fraction is <1%.
- Similar results with different readout speeds.

Chip 1 test example

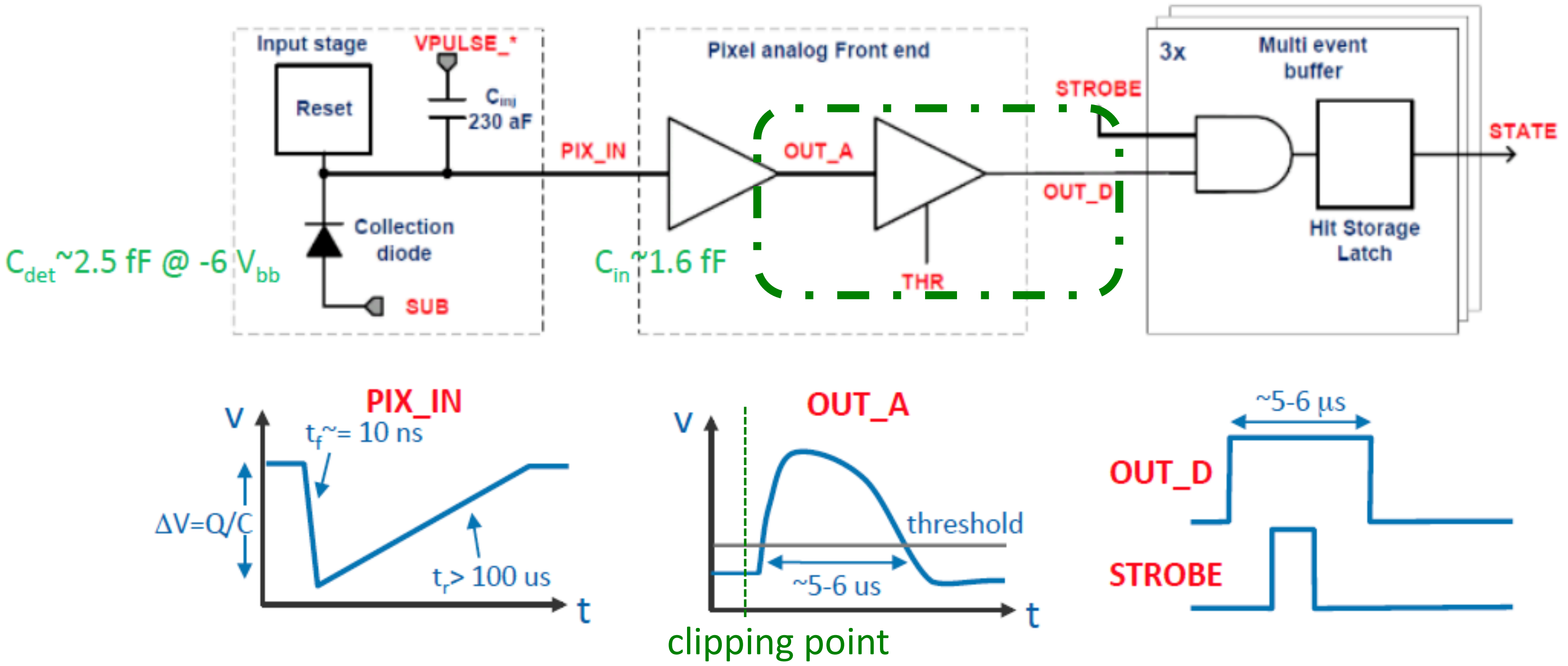


No. of 0 hits
777
Cold channel
1
Hot channel
0
Bad fraction
0.15%

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



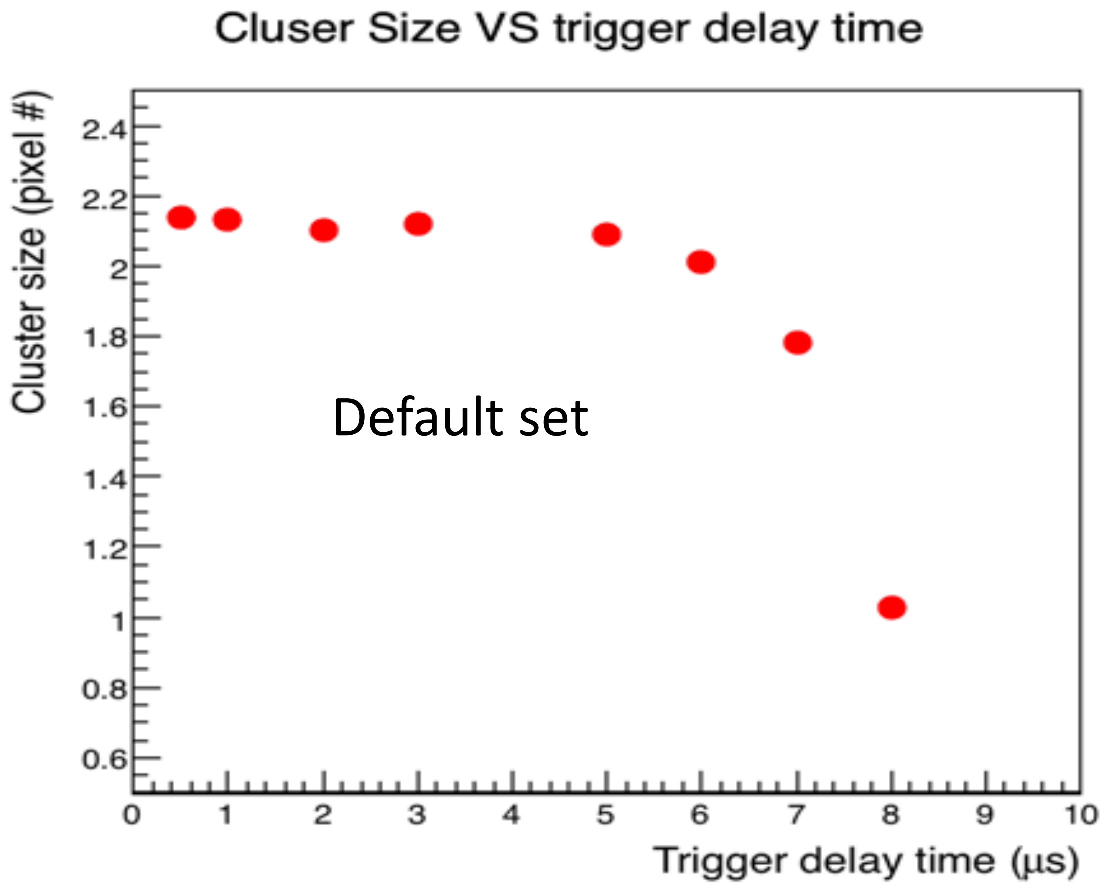
ALPIDE Readout Optimization and Trigger Latency Study

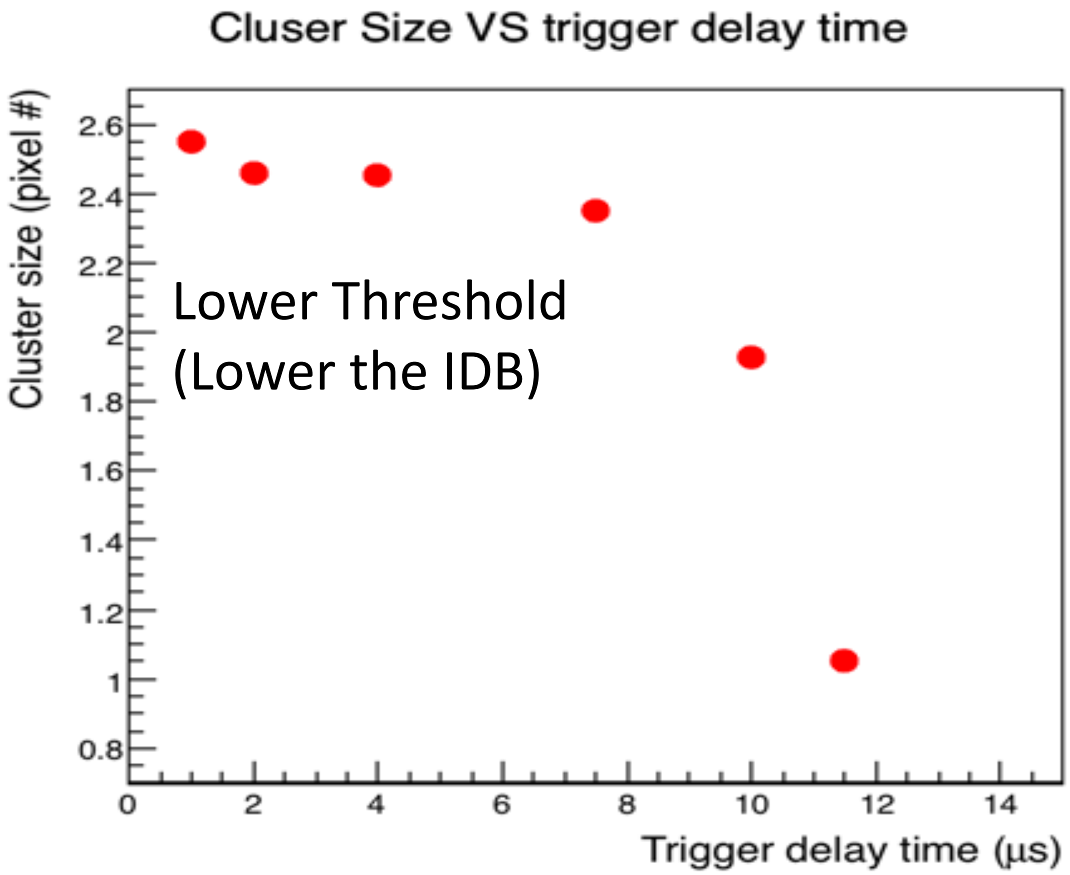


- OUT_A clipping: VCLIP. Decreasing VCLIP decreases clipping point.
- OUT_A returns to baseline time: ITHR, VCLIP. Increasing ITHR decreases discharge time, and decreasing VCLIP decreases discharge time after clipping.
- OUT_D return to baseline time: IDB. Increasing IDB increasing charging time hence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

Trigger Latency Scan

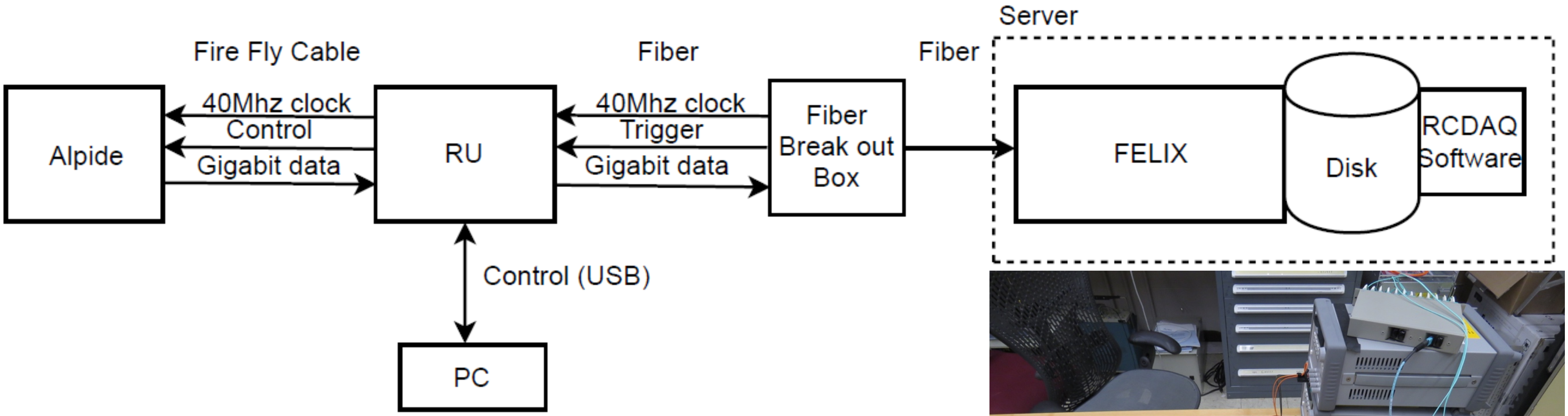
- Lower the OUT_D threshold (IDB) increases the trigger duration time, but also increases the cluster size which might include more background hits.

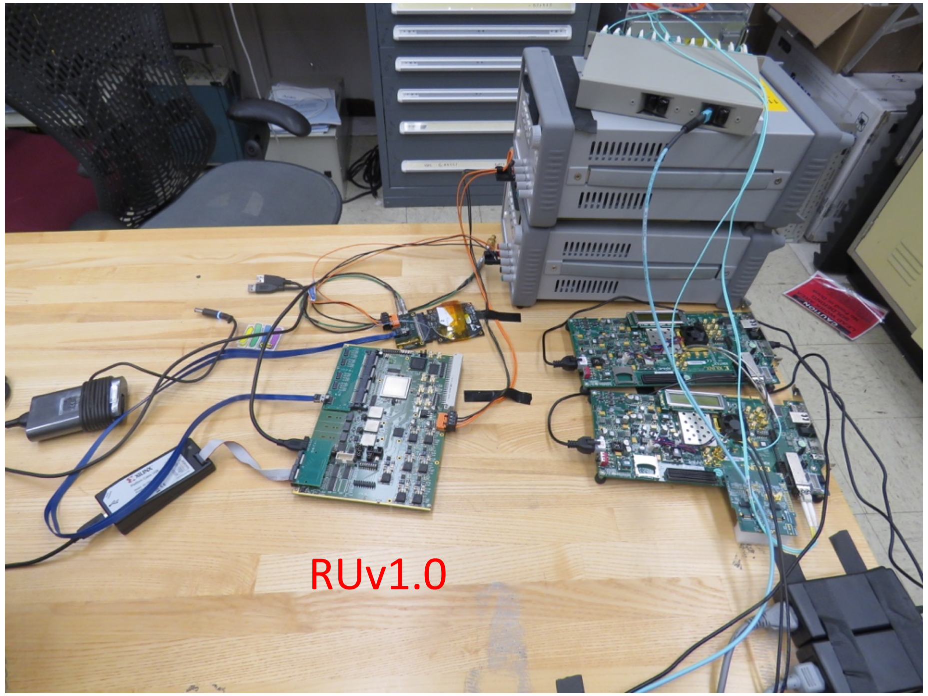




First Full Chain Readout: Success!

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

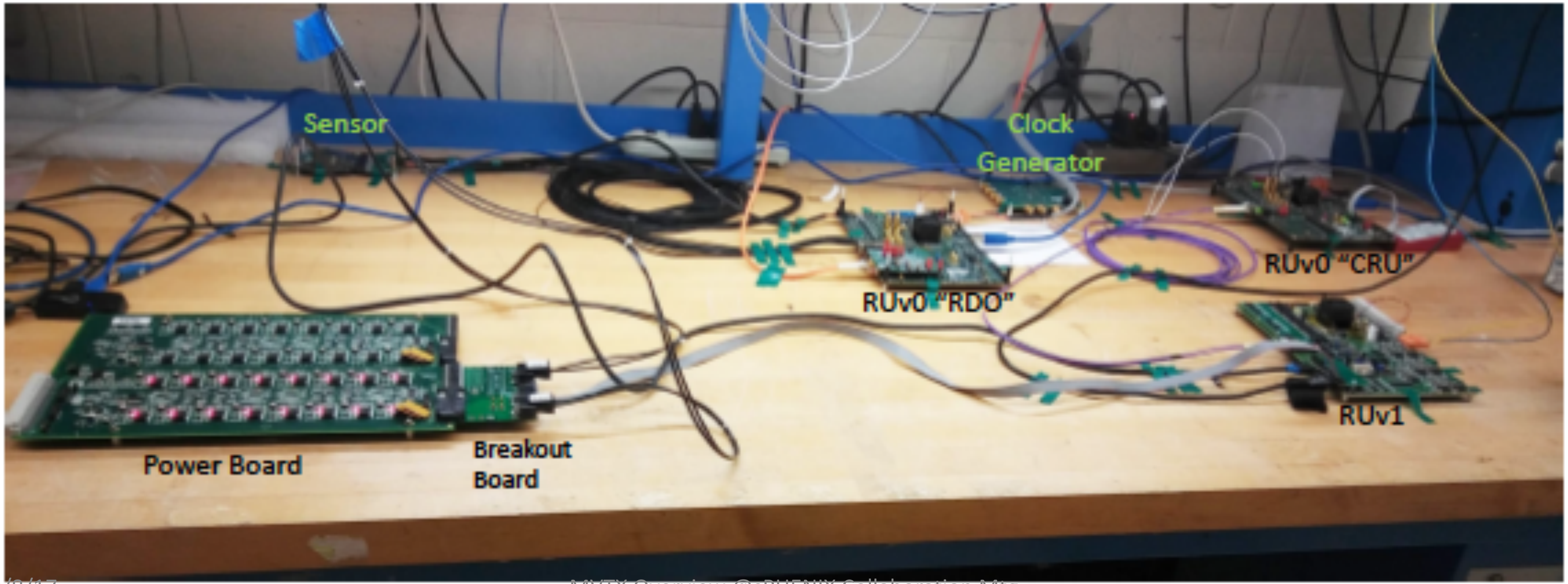
Parallel Effort at UT-Austin – Shared R&D

From Jo

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

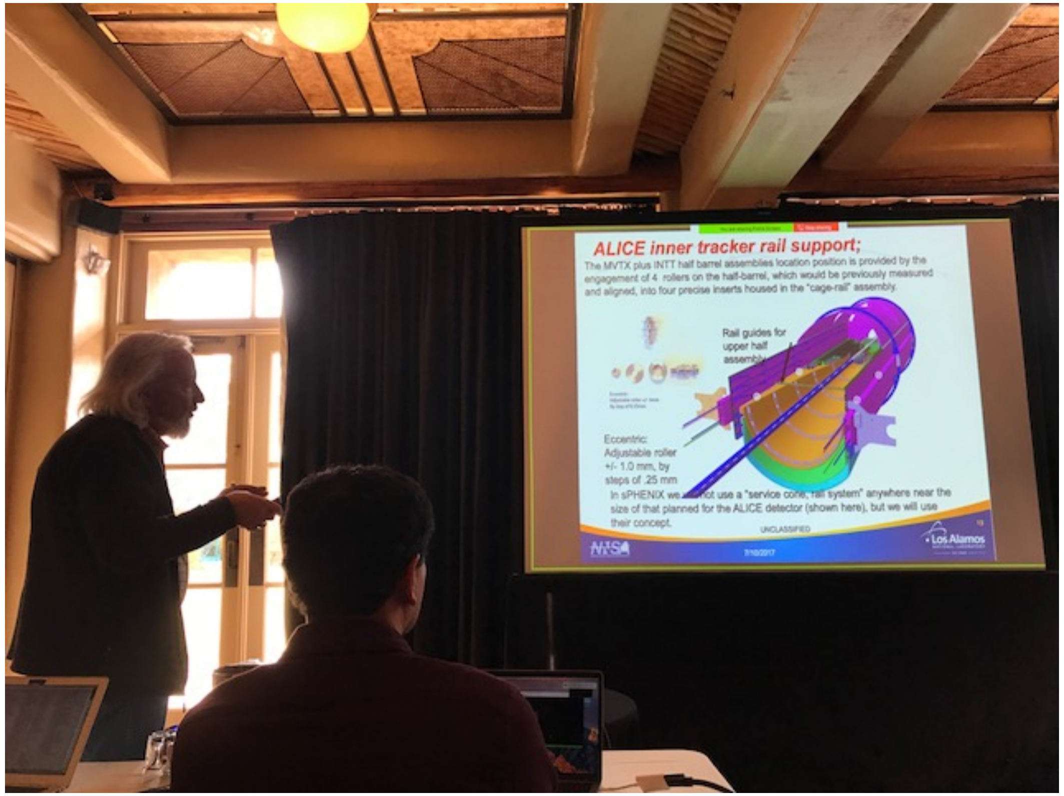


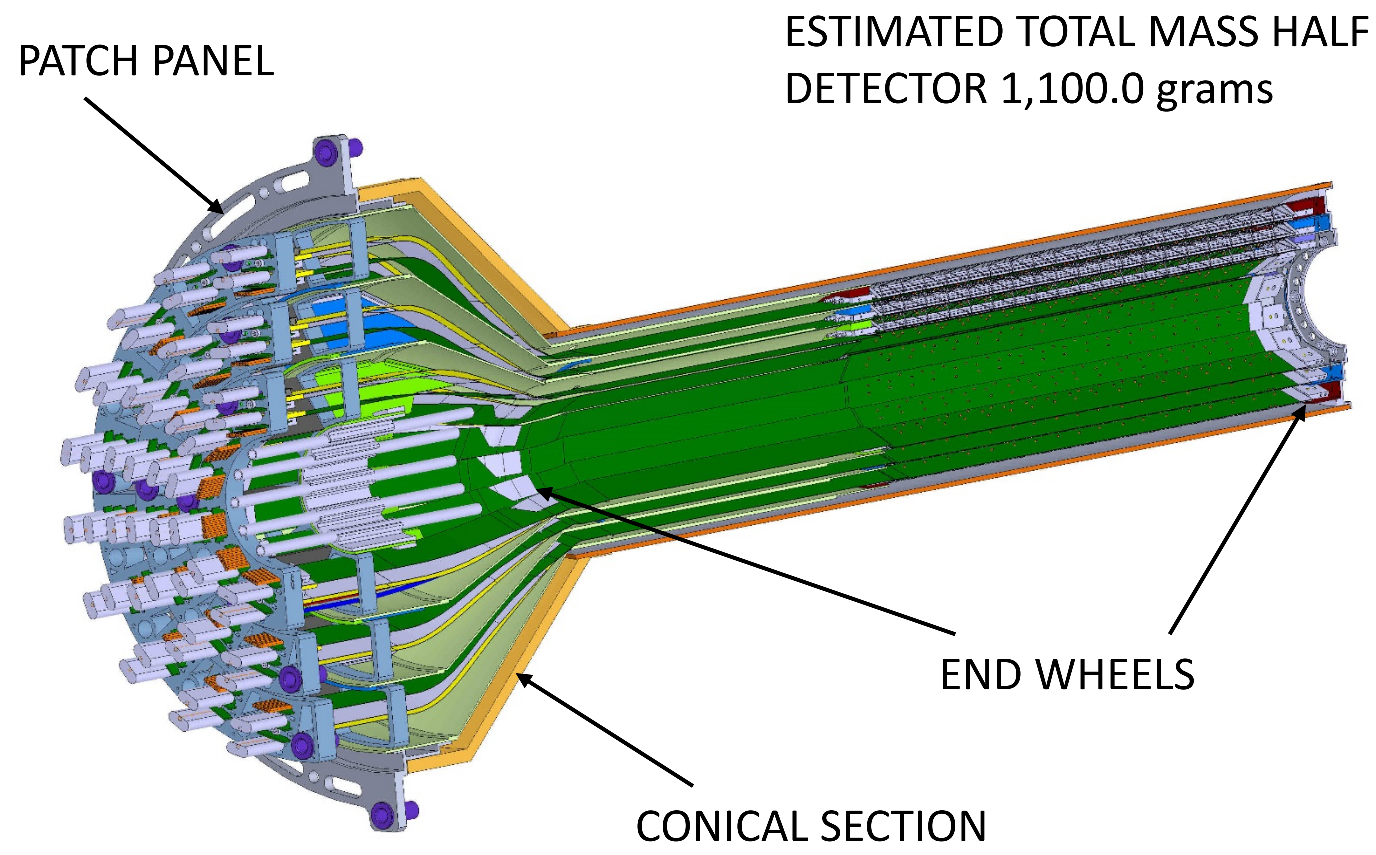
Mechanical Integration

Walt, Bob et al

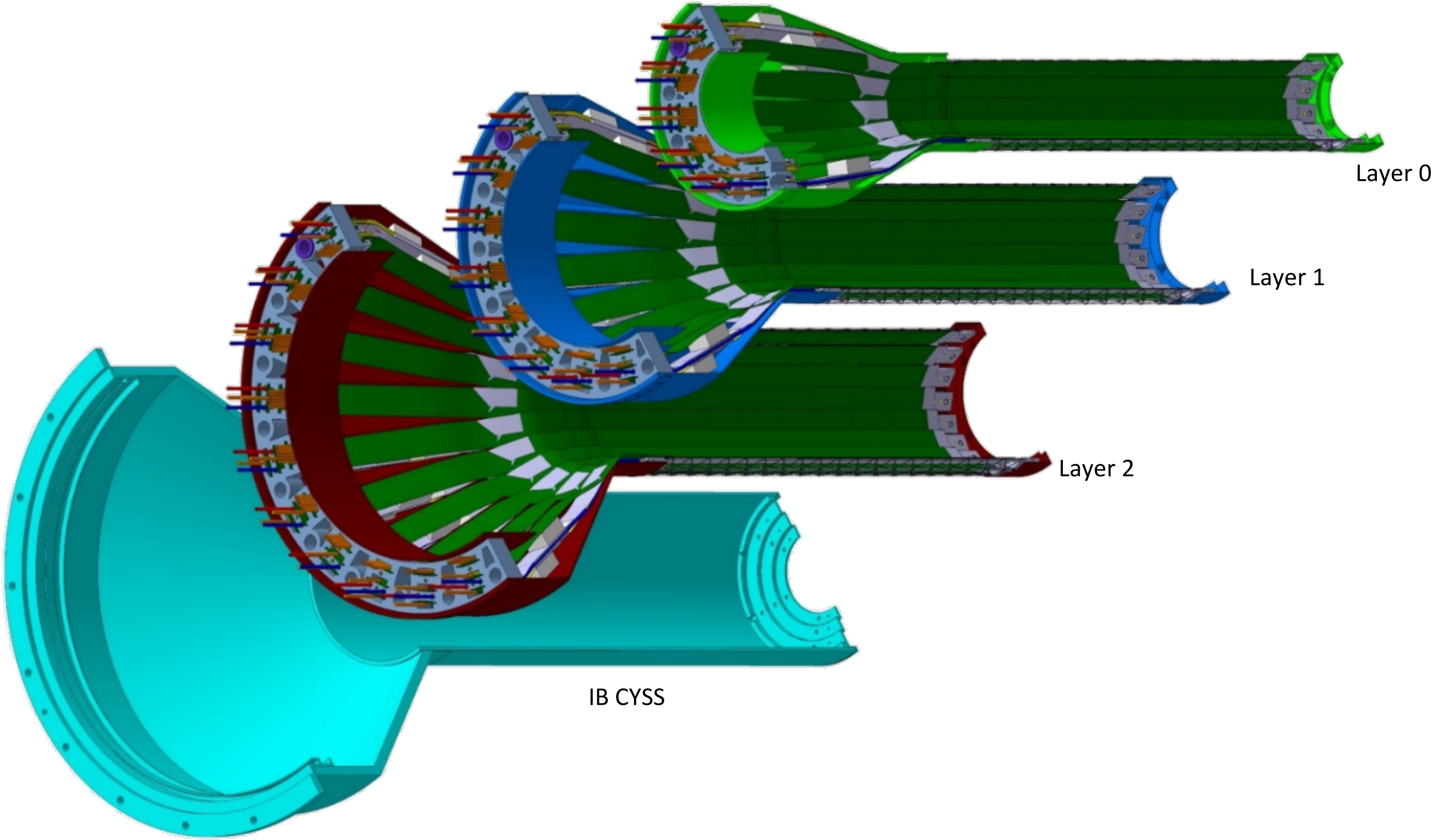
Update from MVTX mechanics workfest

Incorporates the current INTT model and the TPC as components for the sPHENIX tracking system



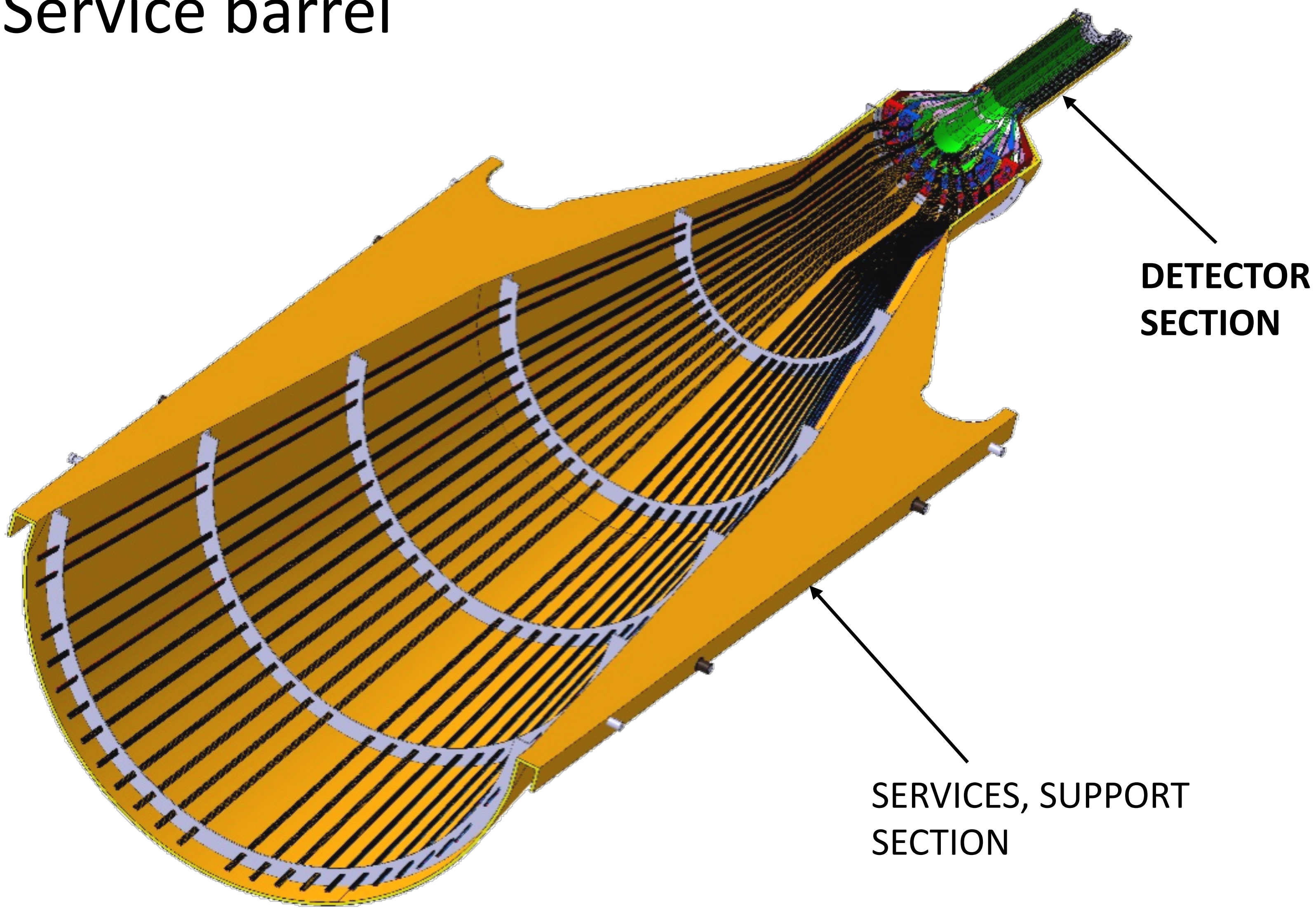


MVTX half detector assembly



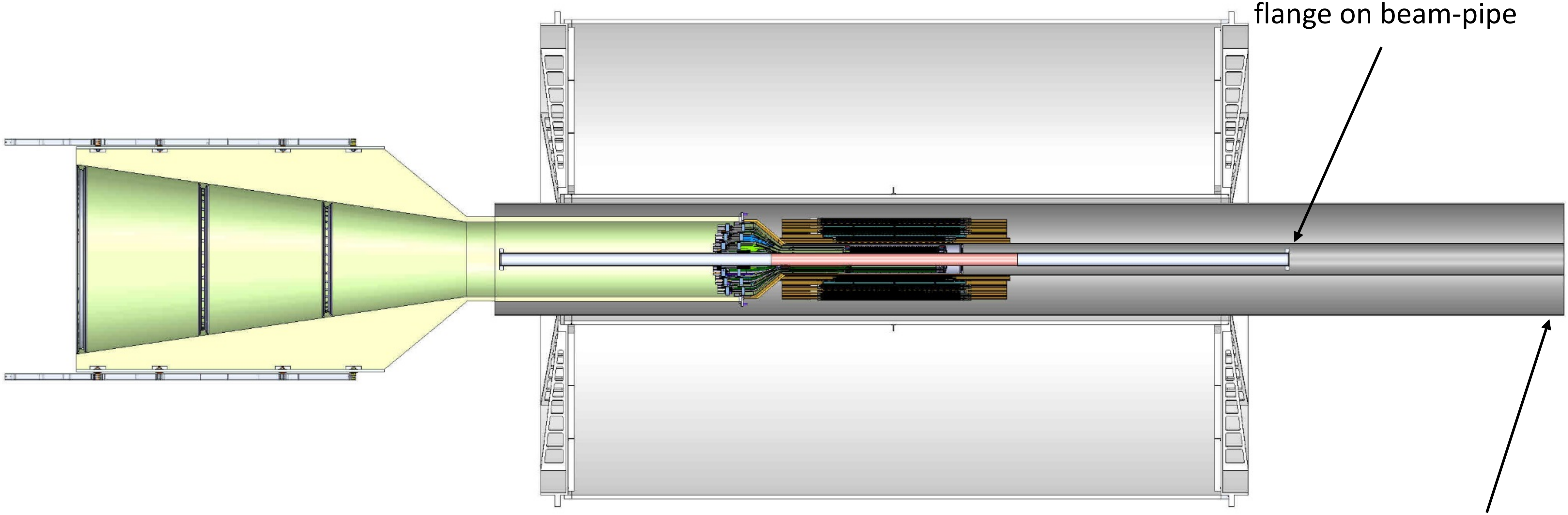
MVTX layer break-out; three sensor layers with a carbon composite outer shell for mechanical stiffness

Service barrel



ALICE HALF-BARREL ASSY

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

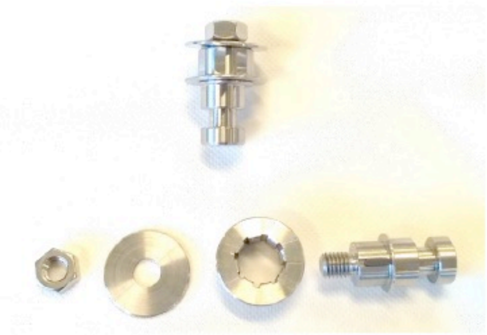


Location of conflat flange on beam-pipe

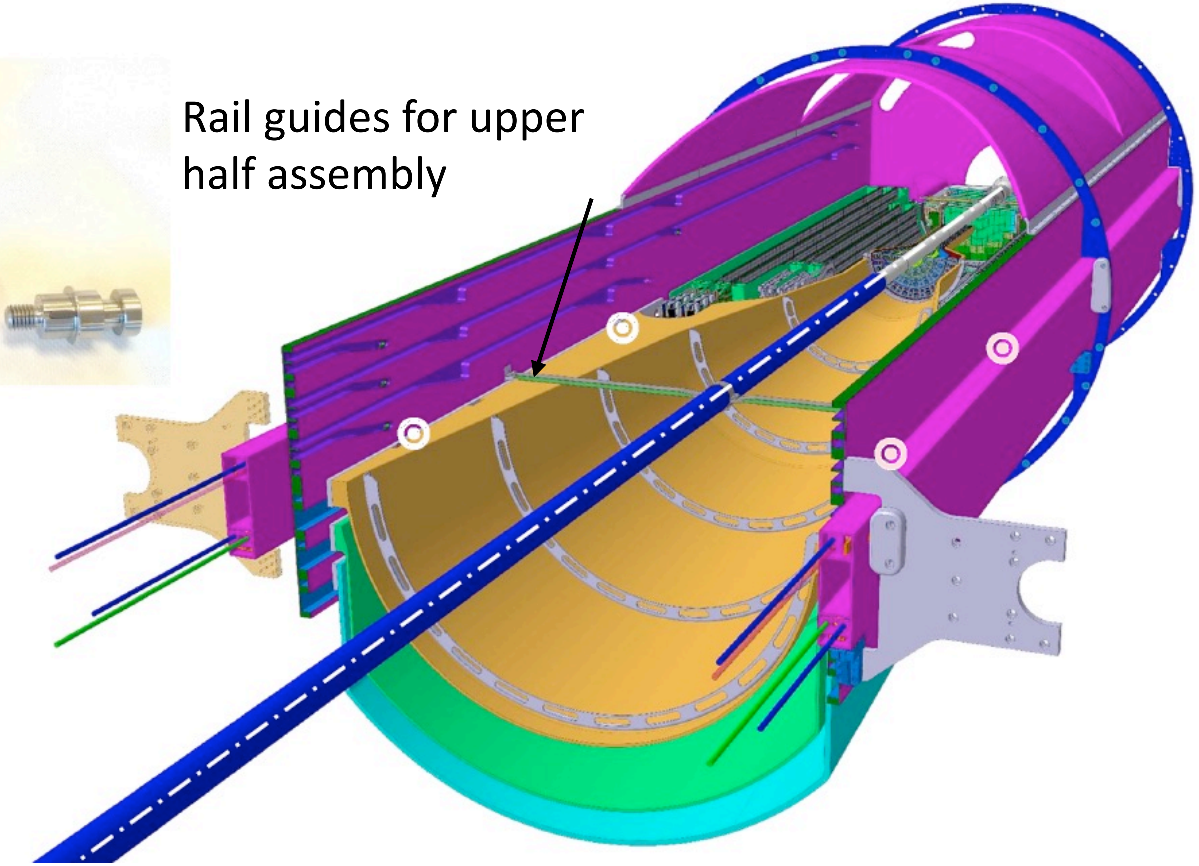
Location in Z where the inner-hcal ends (see control drawing) Z=2175.0 mm

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.



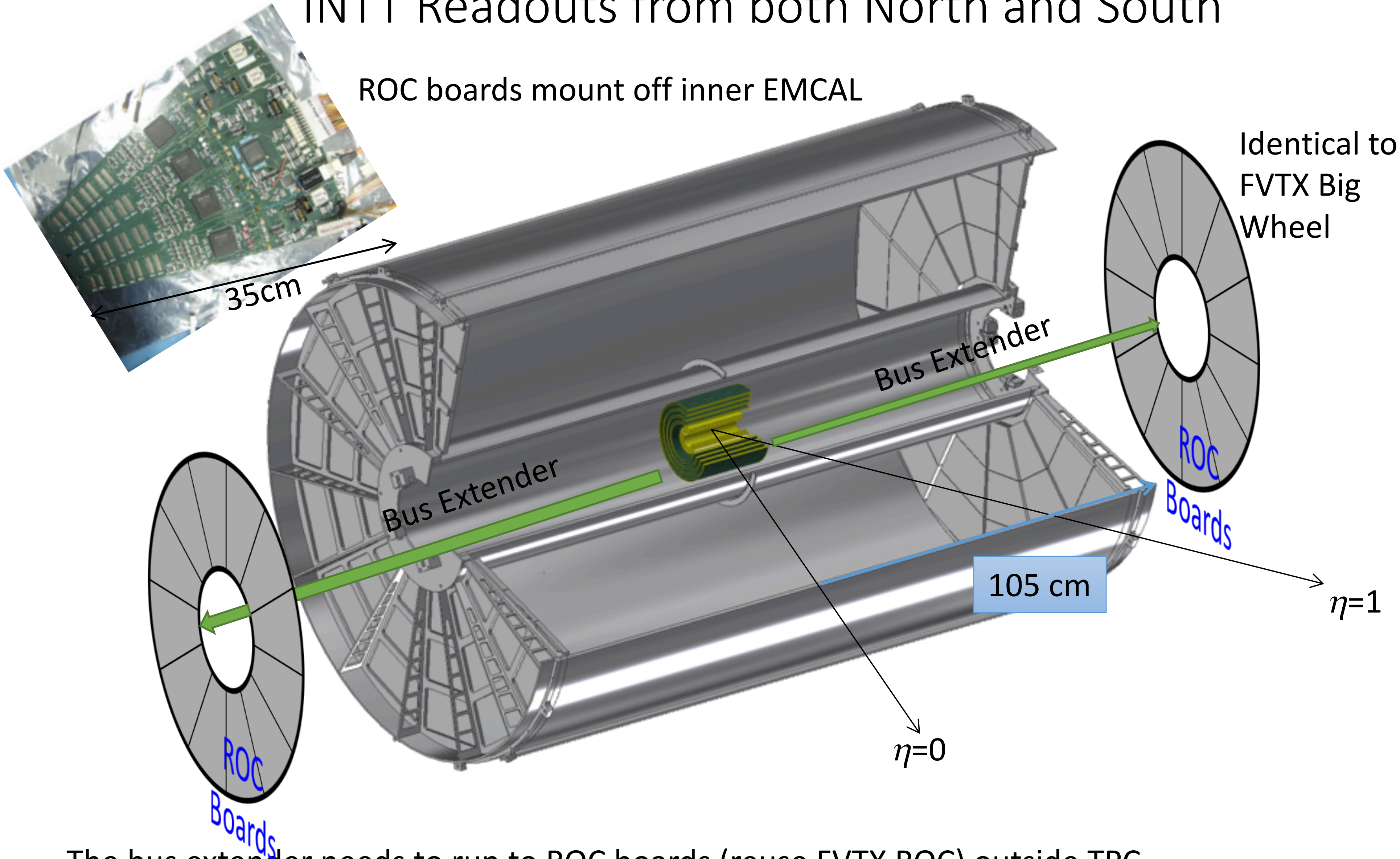
Eccentric:
Adjustable roller +/- 1mm
By step of 0.25mm



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

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.

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.

Ed’s talk

MVTX Schedule and new sPHENIX baseline Plan

- MVTX schedule – align with sPHENIX plan
  - Stave production
    - Following ALICE production: ~8/2018
  - Readout units production
    - Be part of ALICE RU production:
      - FPGA & GTB cost saving
  - Ready for installation: late 2021
    - INTT ready for installation 4/2021
  - MVTX ready for beam
    - sPHENIX day-1

- New sPHENIX baseline schedule
  - CD-1 Review: 5/2018
  - sPHENIX installation
    - 4/2021 – 7/2022
  - sPHENIX ready for beam: 9/2022
  - First collision: 1/2023

Cost and Schedule

Dave's talk

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

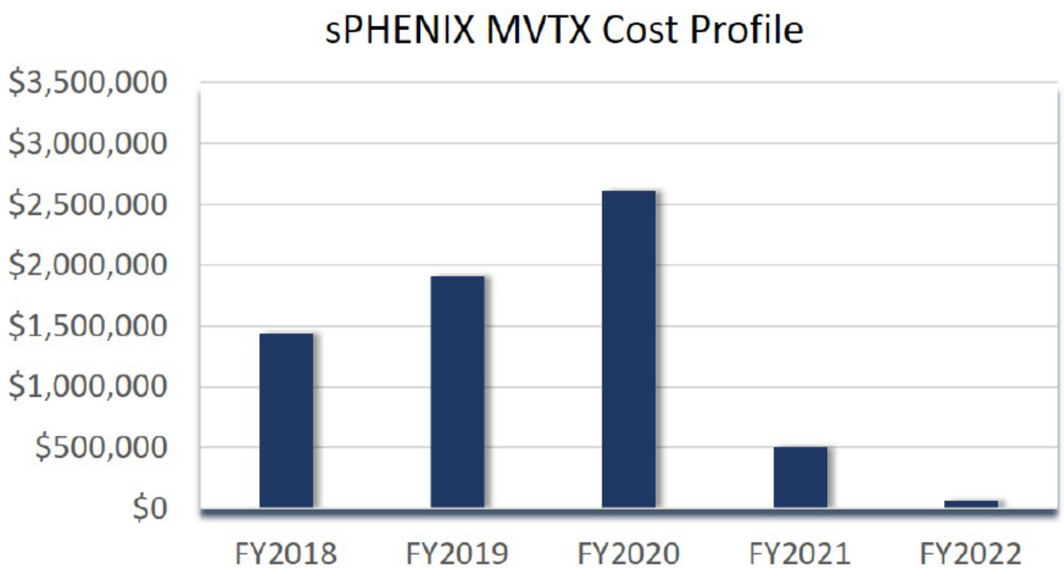


Figure 42: MVTX Funding Profile.

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

Major Cost Items

WBS	Task Name	Cost (K)	Cost with Contingency+ Passthru (K)
1.5.3.1.1	Produce 84 staves	$966	$1337
1.5.2.2	Readout Units(RDO)	$480	$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

Project Organization

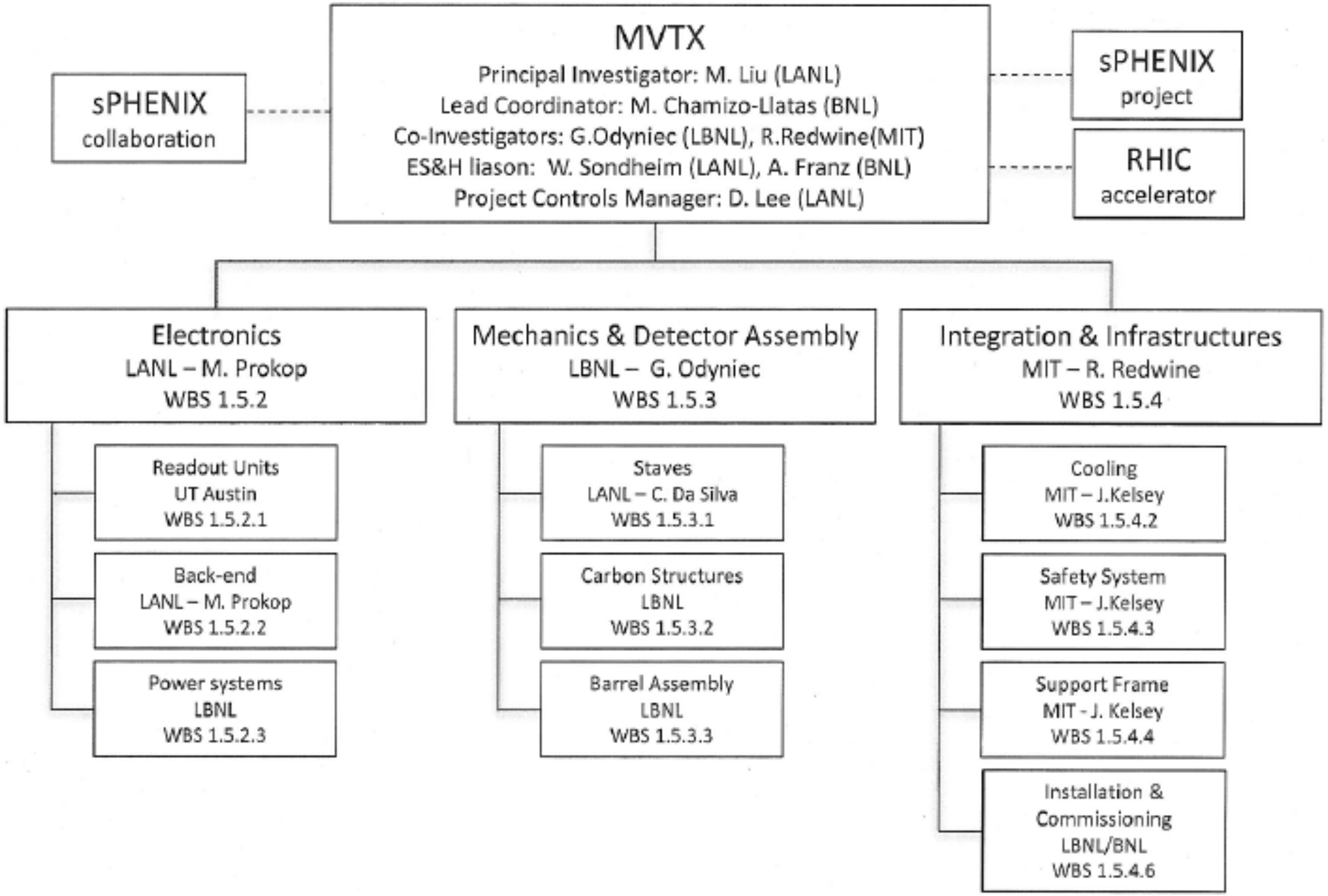


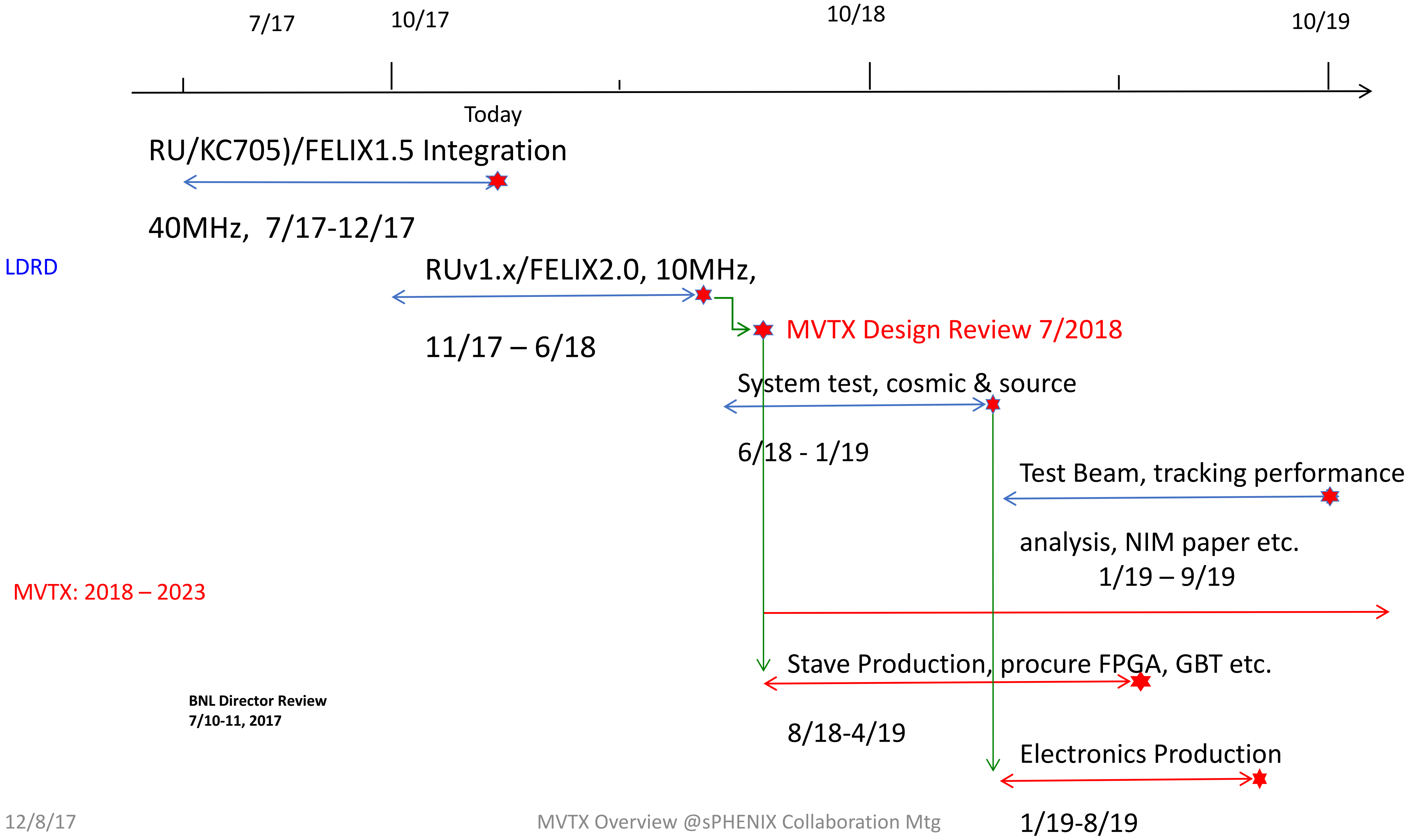
Figure 40: Organization chart of the MVTX project.

Summary

- MVTX proposal document updated
  - Addressed recommendations from last Director's Review
  - Expanded science
  - Updated cost and schedule
  - To be submitted to DOE in Jan 2018
- Excellent progress in R&D
  - Readout and controls proof-of-principle demonstrated
  - Conceptual mechanical system design developed
- MVTX+INTT+TPC mechanical integration in progress
  - sPHENIX wide coordination needed
- Ready for sPHENIX Day-1 Physics

Backup slides

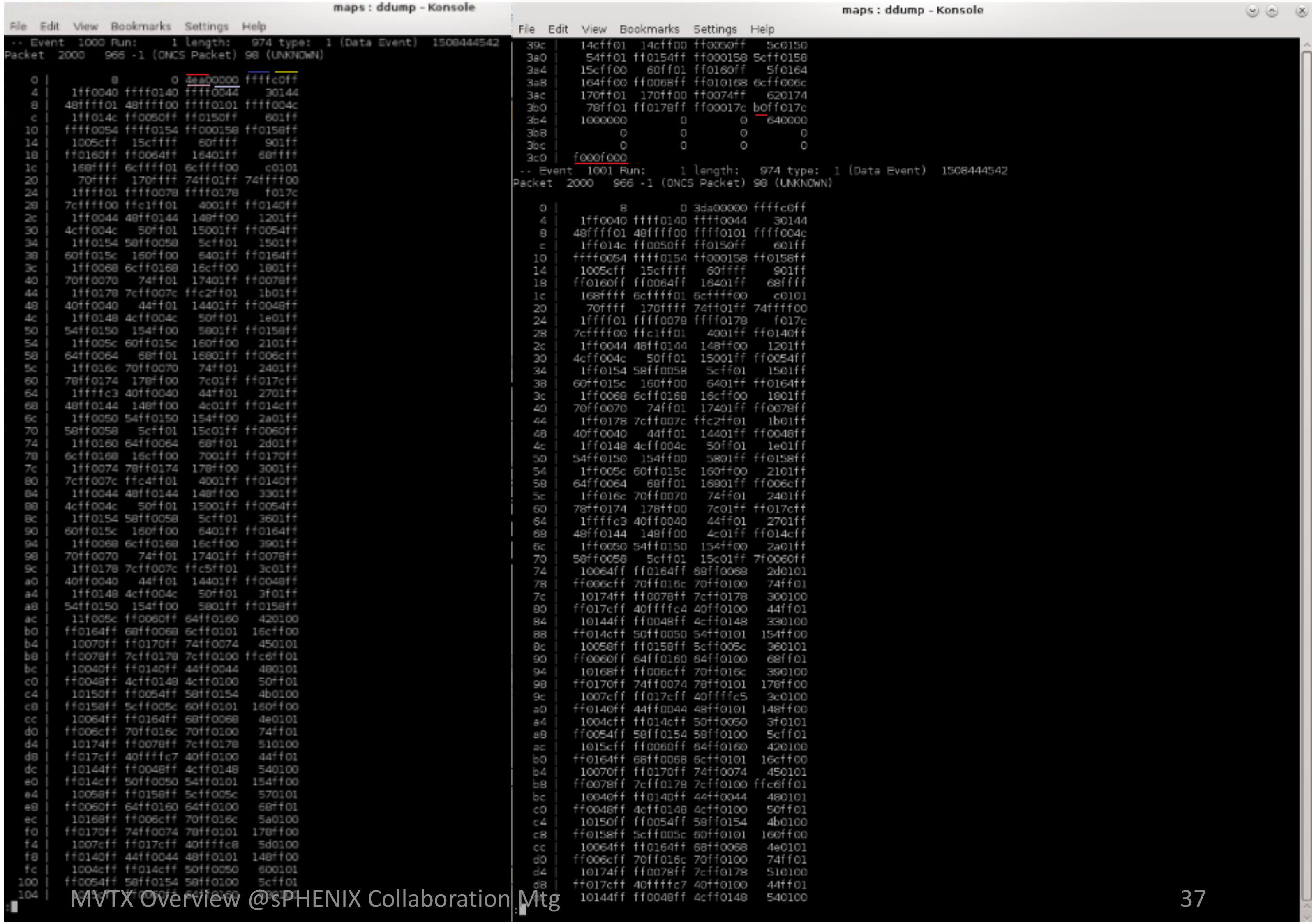
LDRD – MVTX/sPHENIX Key Tasks/Milestones



BNL Director Review
7/10-11, 2017

RC DAQ event Data Screen Shot

- Rcdaq receiving events from KC705 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

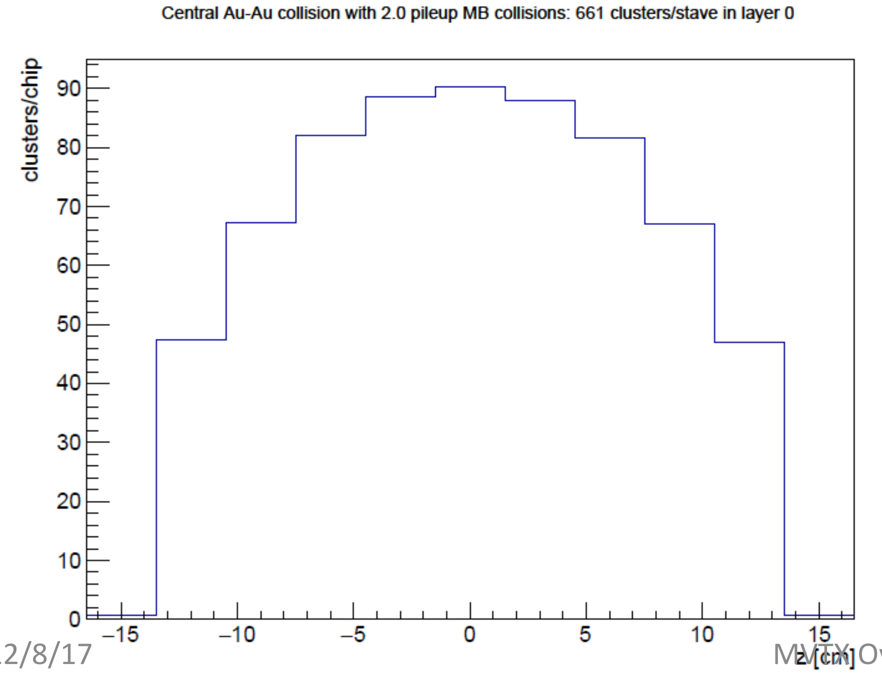


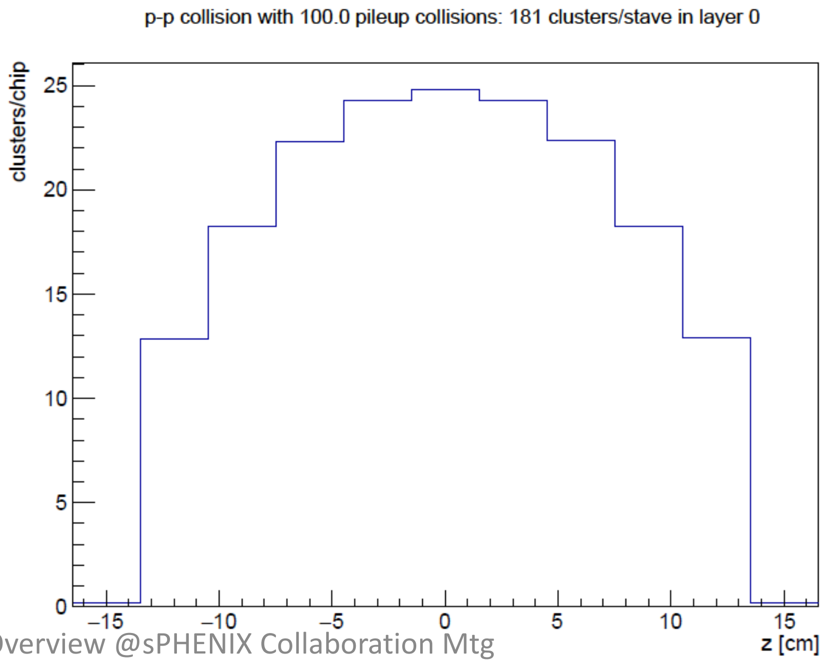
Calculations

	Collision Rate
Au Au	200kHz
P P	10Mhz

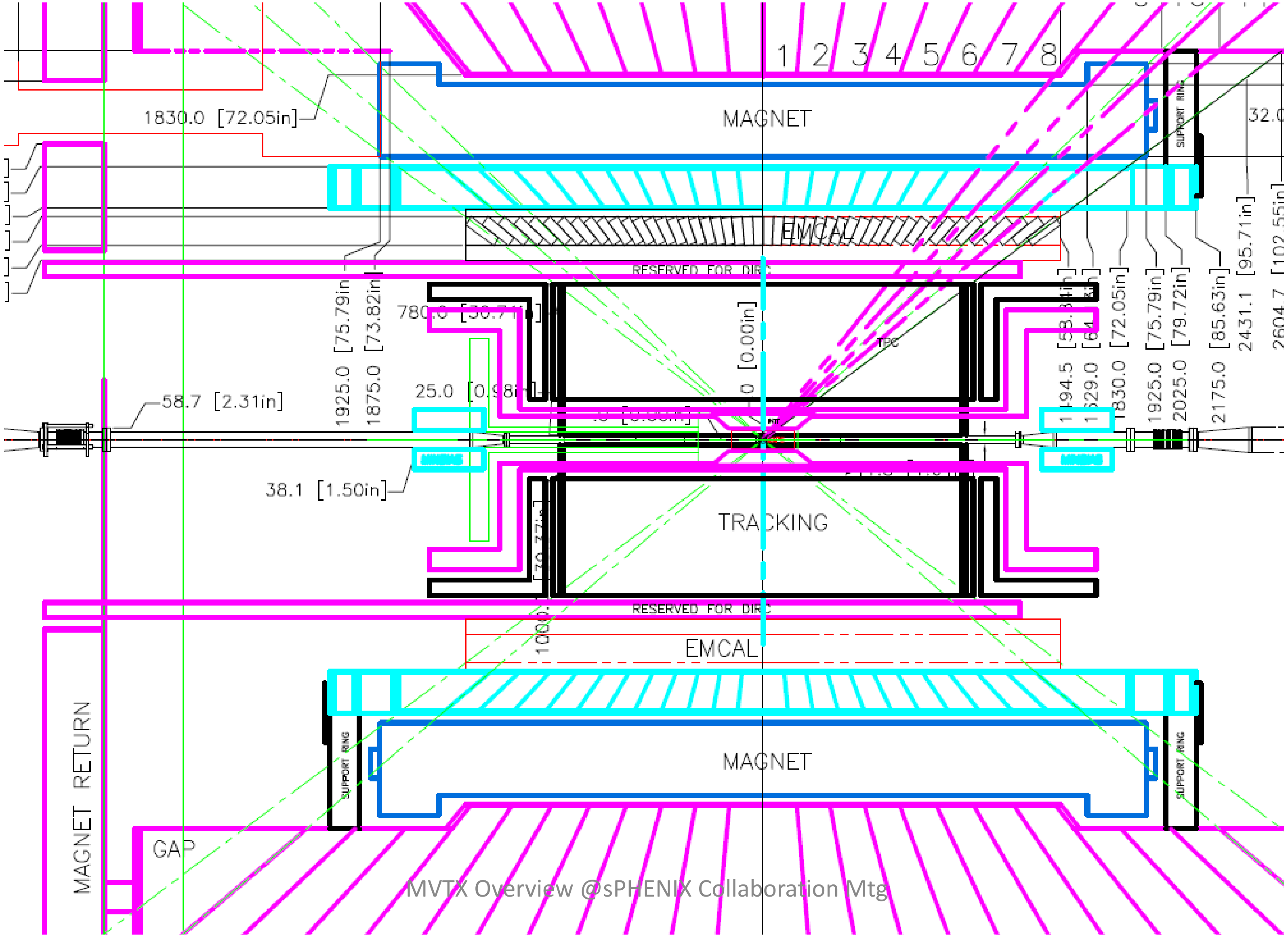
- Assume 10us window and cluster size 3

	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

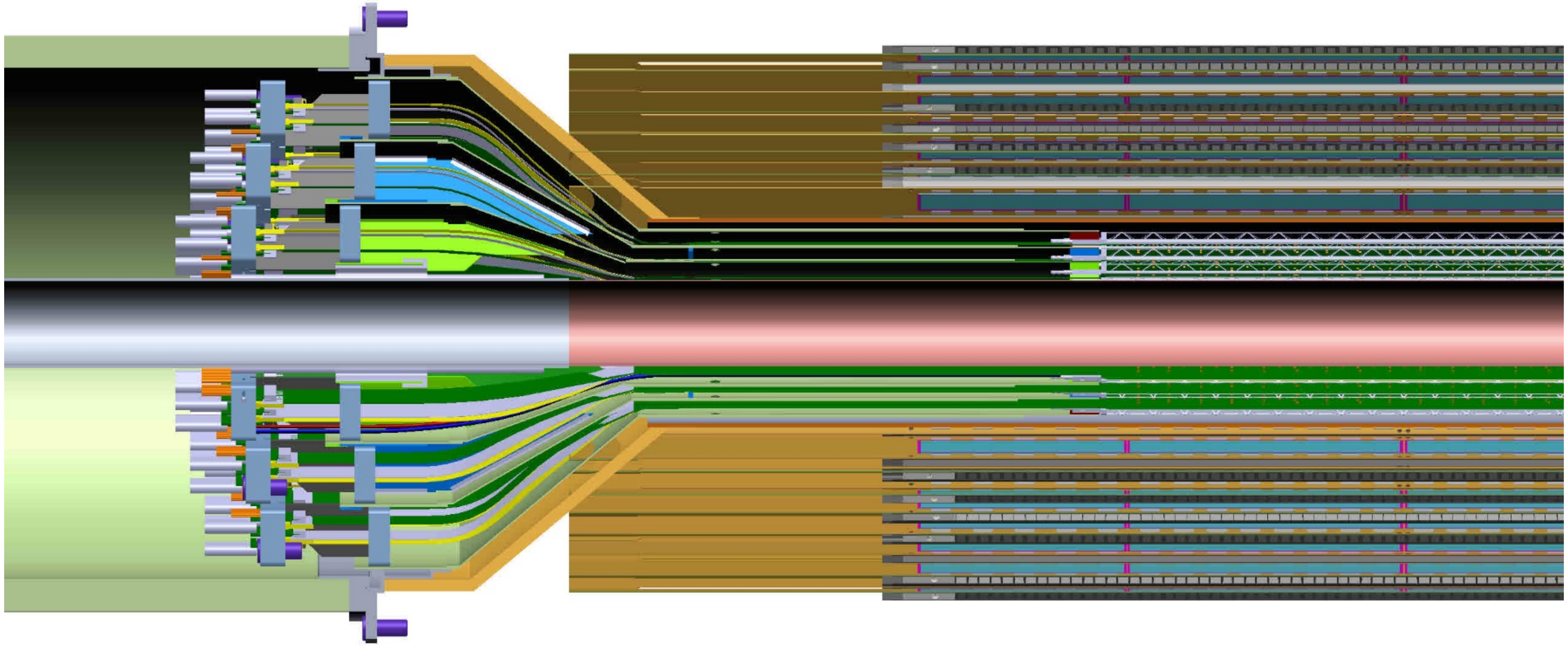




BNL control envelope drawing; Z location of the inner hcal is at 2175,0mm

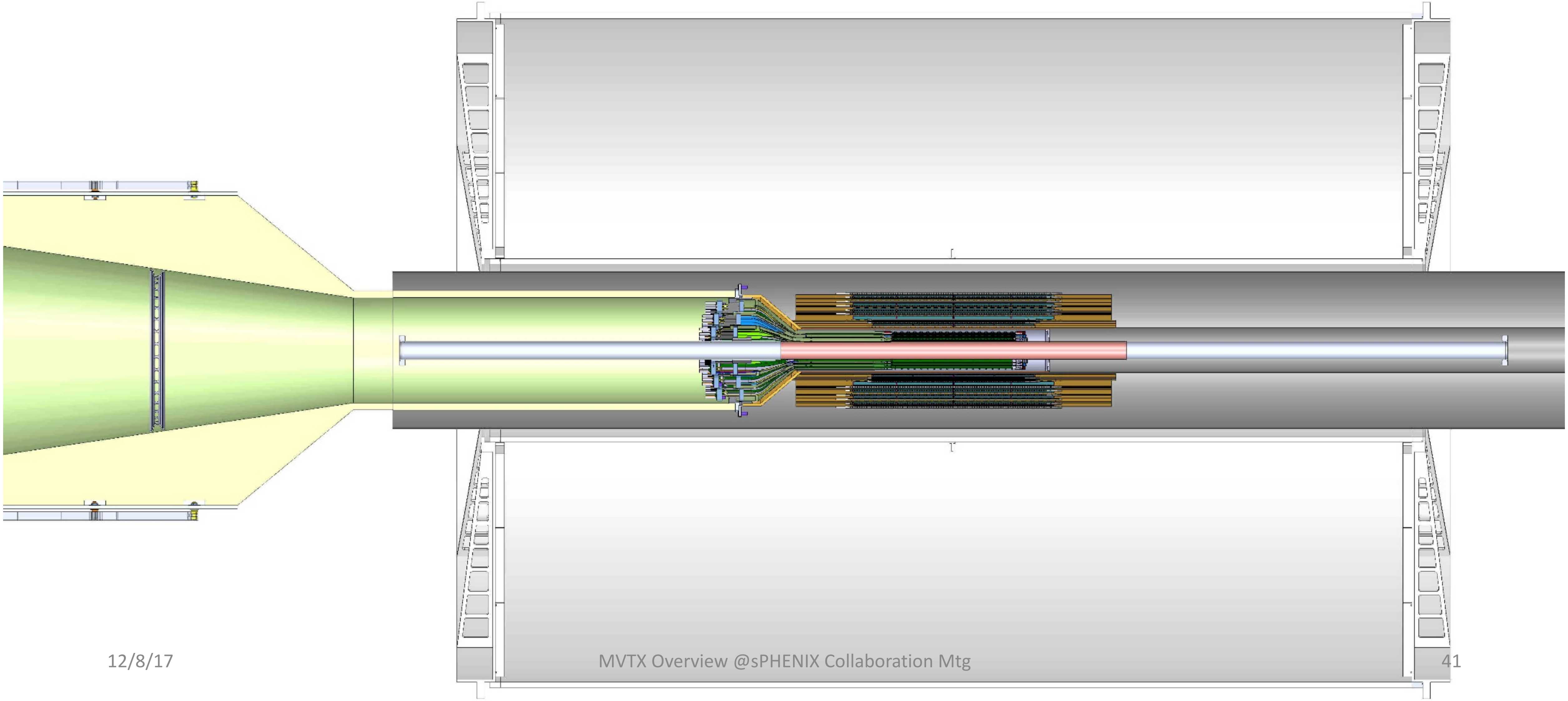


Adding the INTT to model of MVTX in sPHENIX

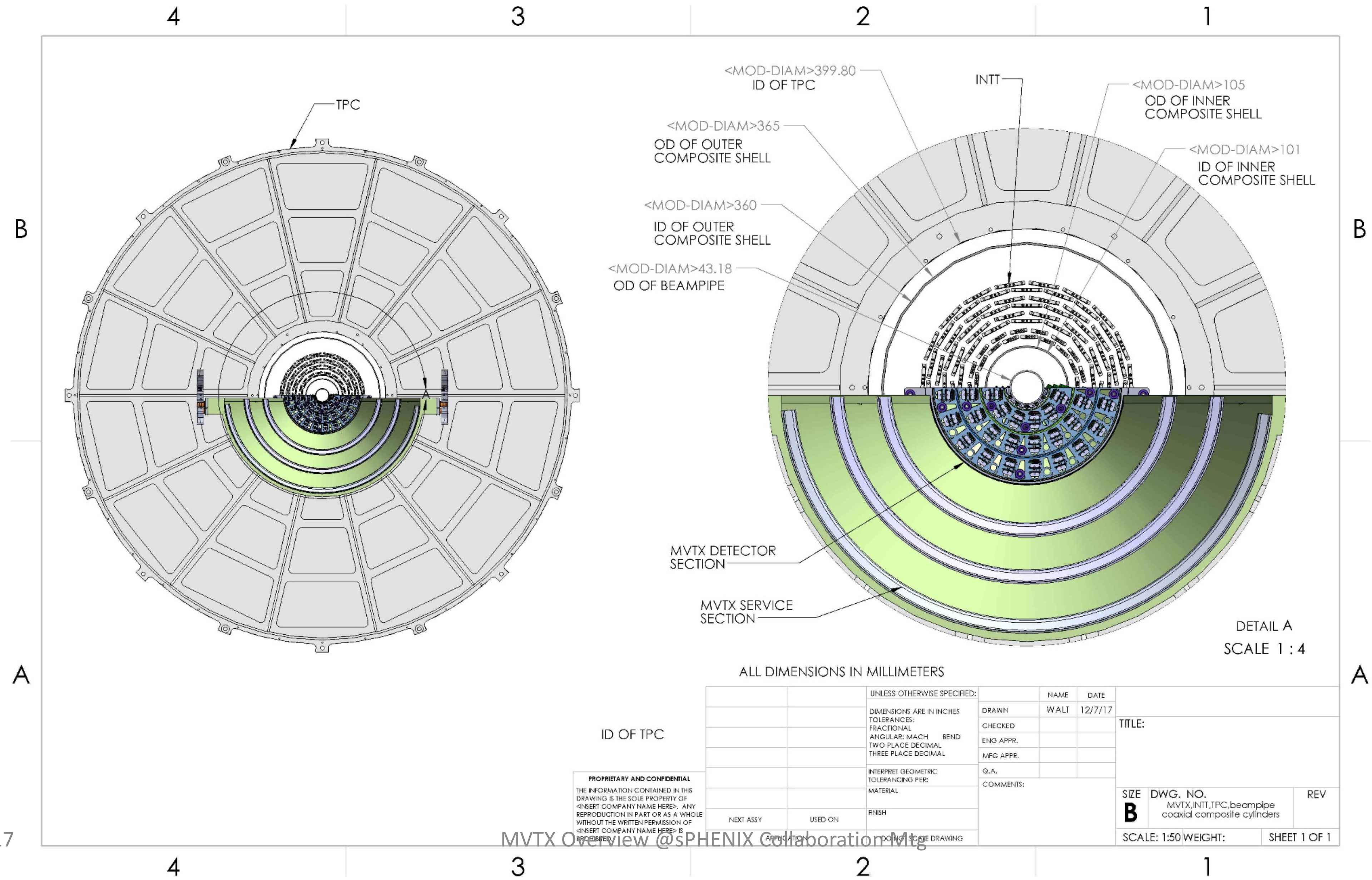


It is clear from this detail view the conical region of the MVTX detector barrel with the INTT that the MVTX will need to translate in Z by at least another 50.0 mm in addition to the 180.0mm that is seen in this model

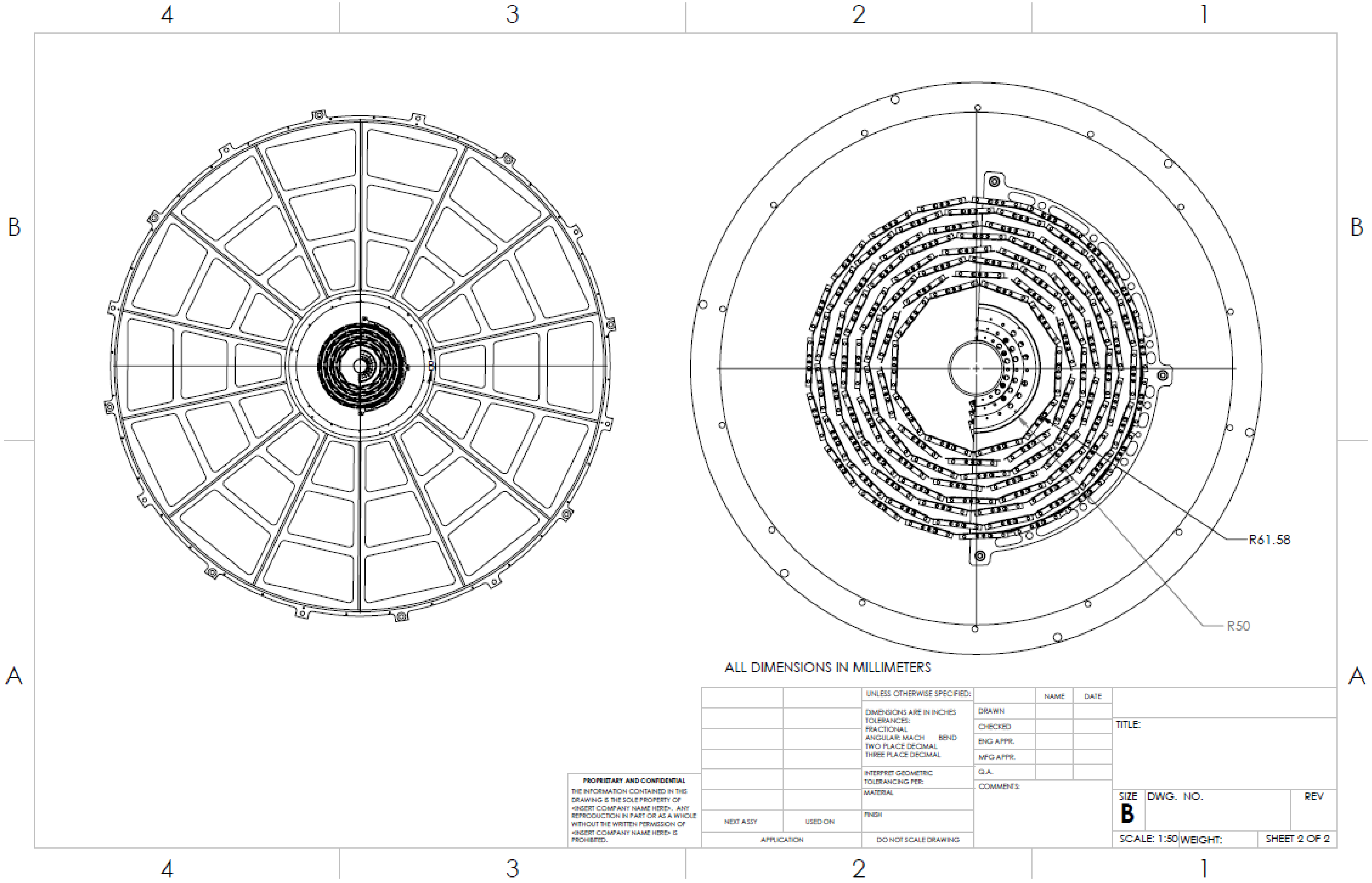
Detail view of MVTX, where the conical region has been translated by an additional 50.9 mm, along with the INTT and two concentric composite cylinders



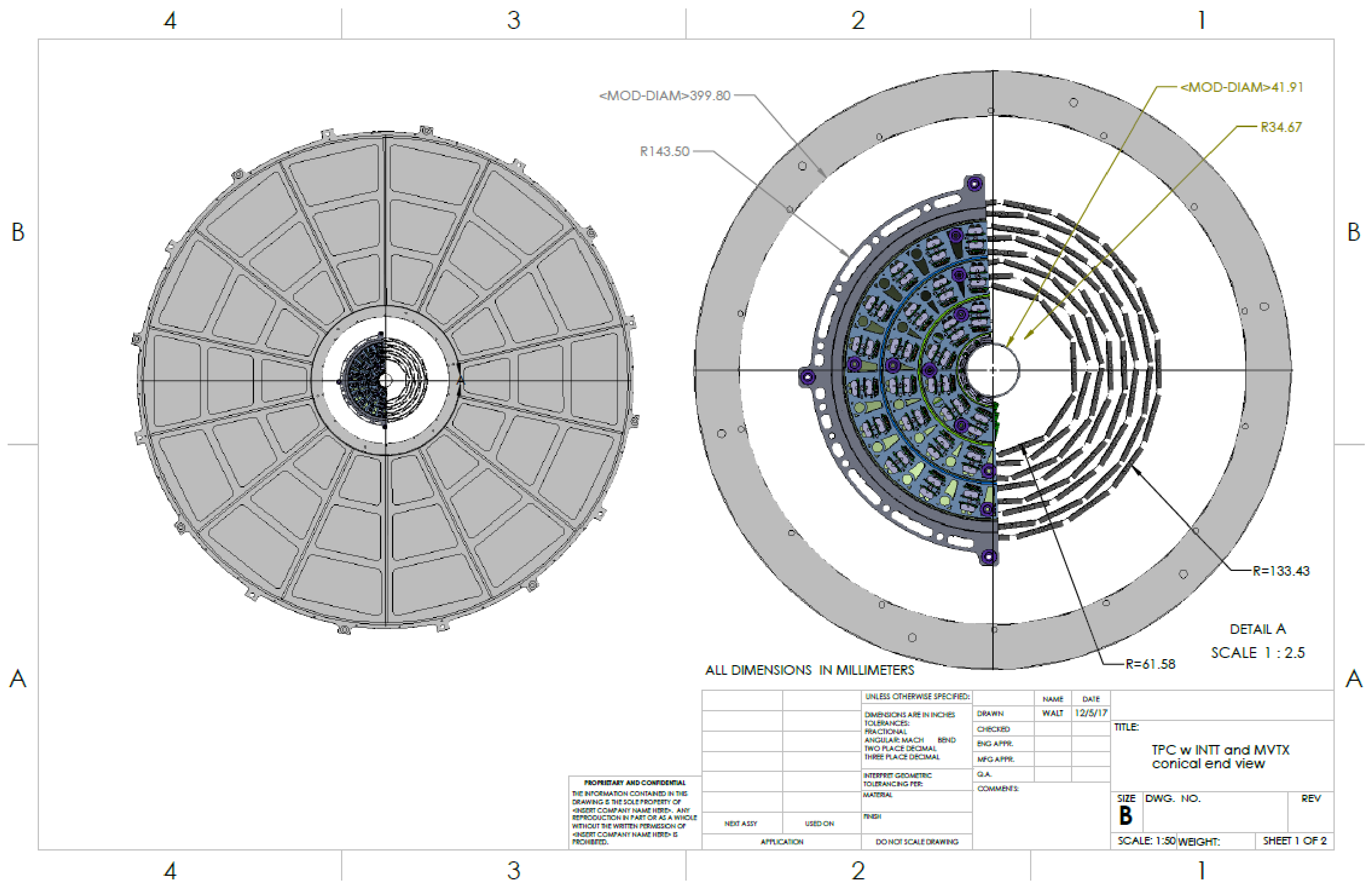
Cross-section view from CAD model of MVTX, INTT, TPC, beam-pipe, plus two composite conical shells



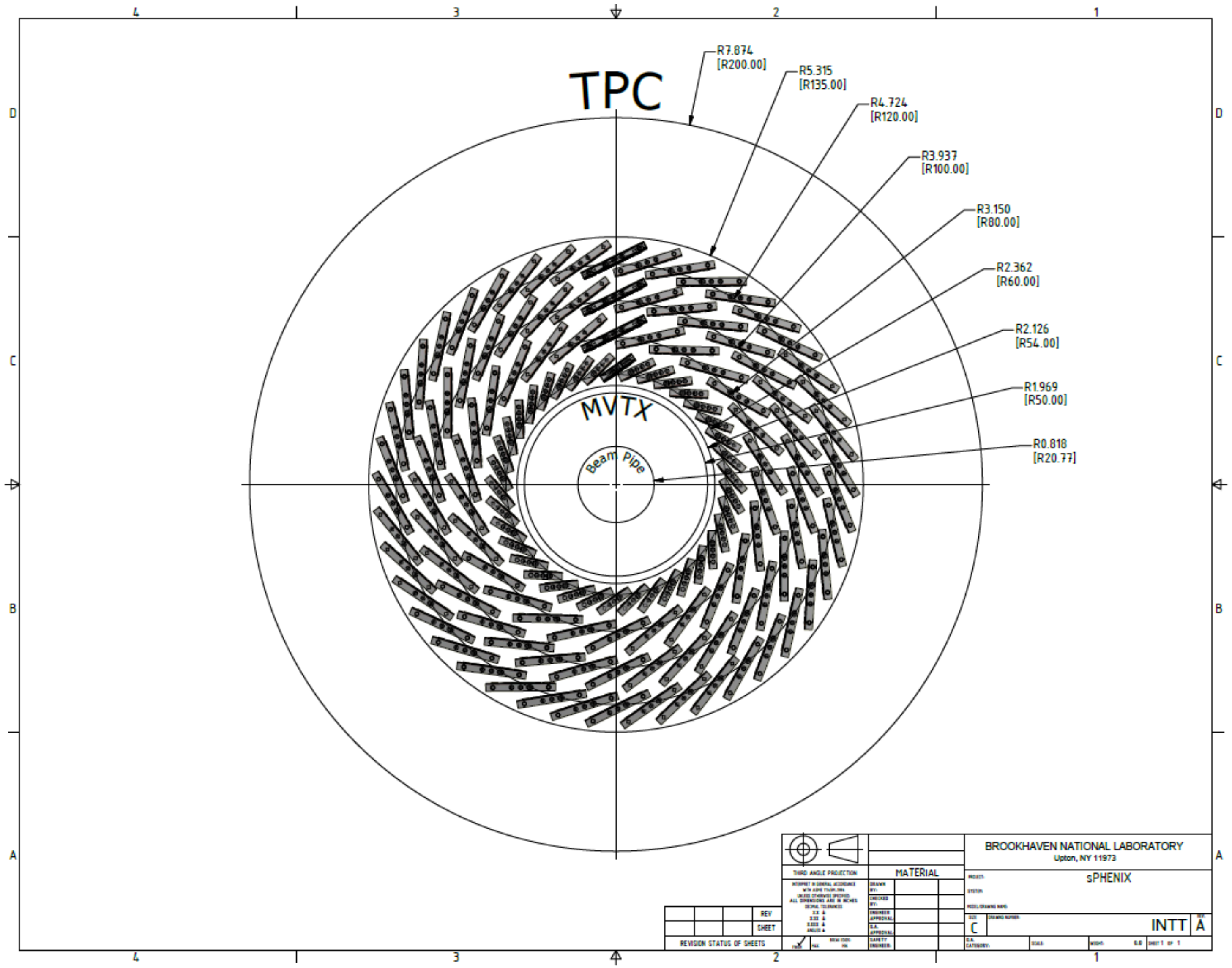
Gap between conical shell of MVTX and inner layer of INTT is 11.58 mm



56.0 mm gap between INTT and inner radius of TPC



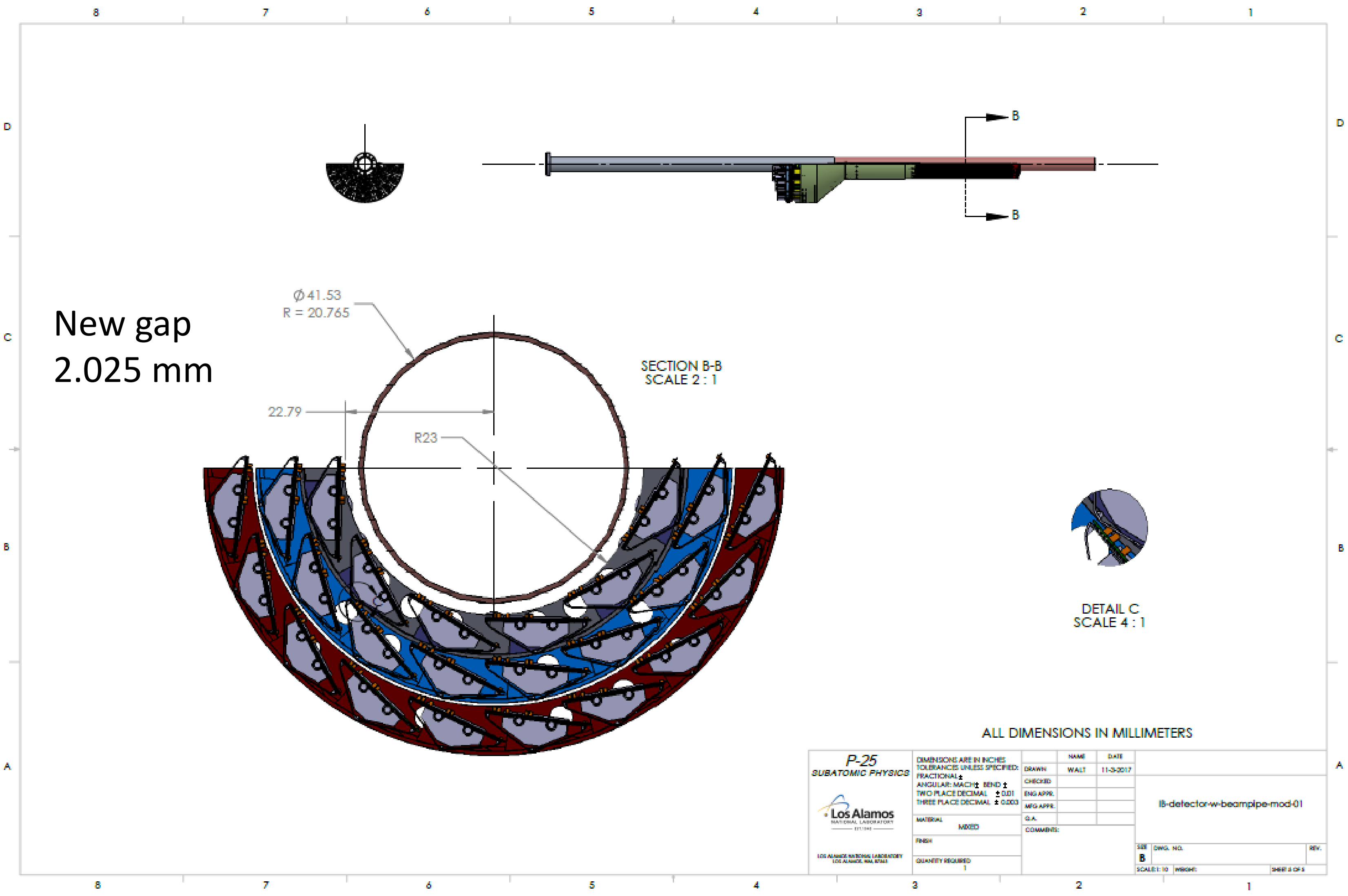
Earlier model for the INTT, chevron configuration, inner layer half ladders in width;



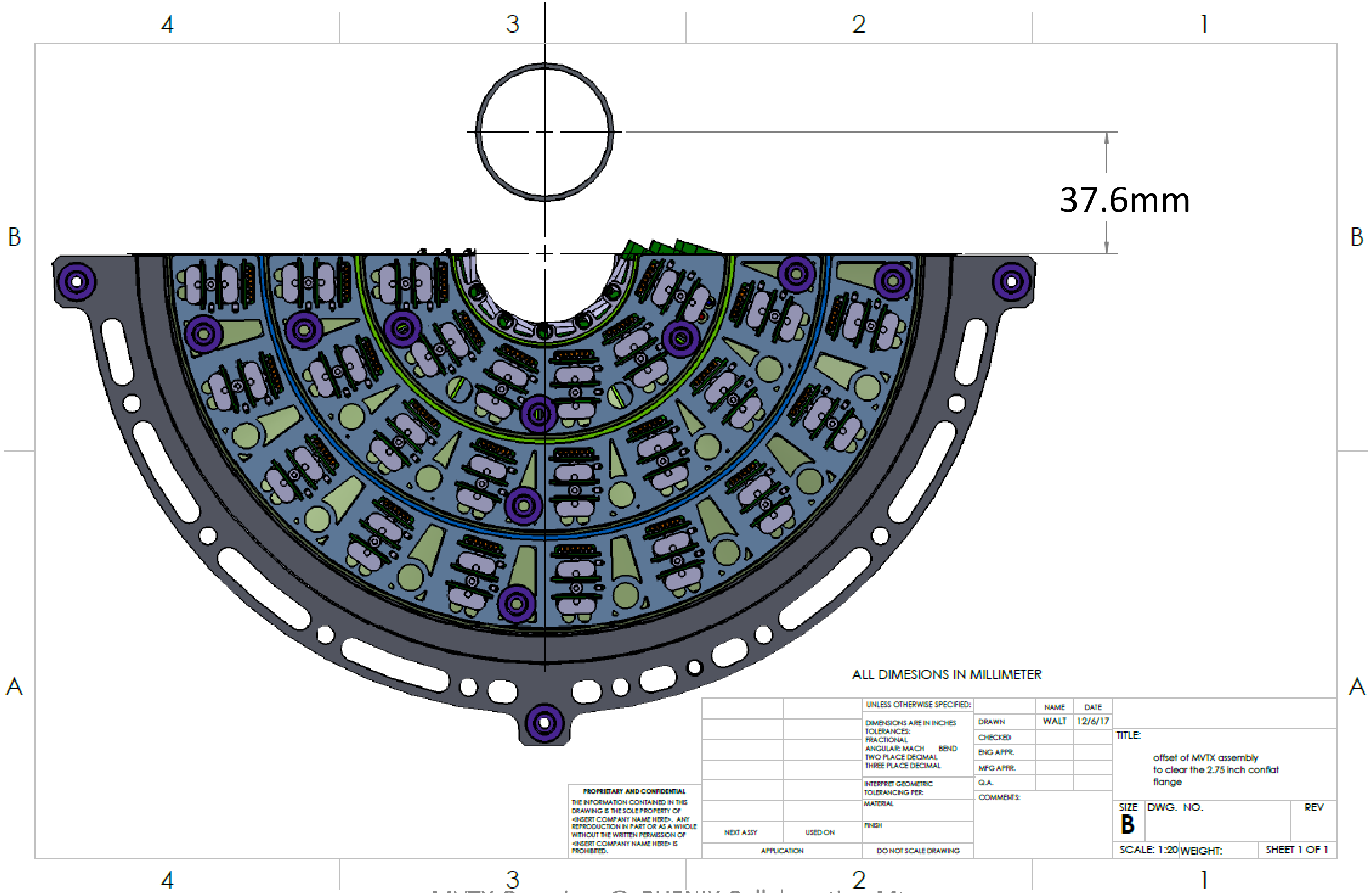
Number of ladders:
Layer 0 – 38 half ladders,
Layer 1 – 26
Layer 2 – 34
Layer 3 - 42

Offset from OD of beampipe and innermost component of the MVTX

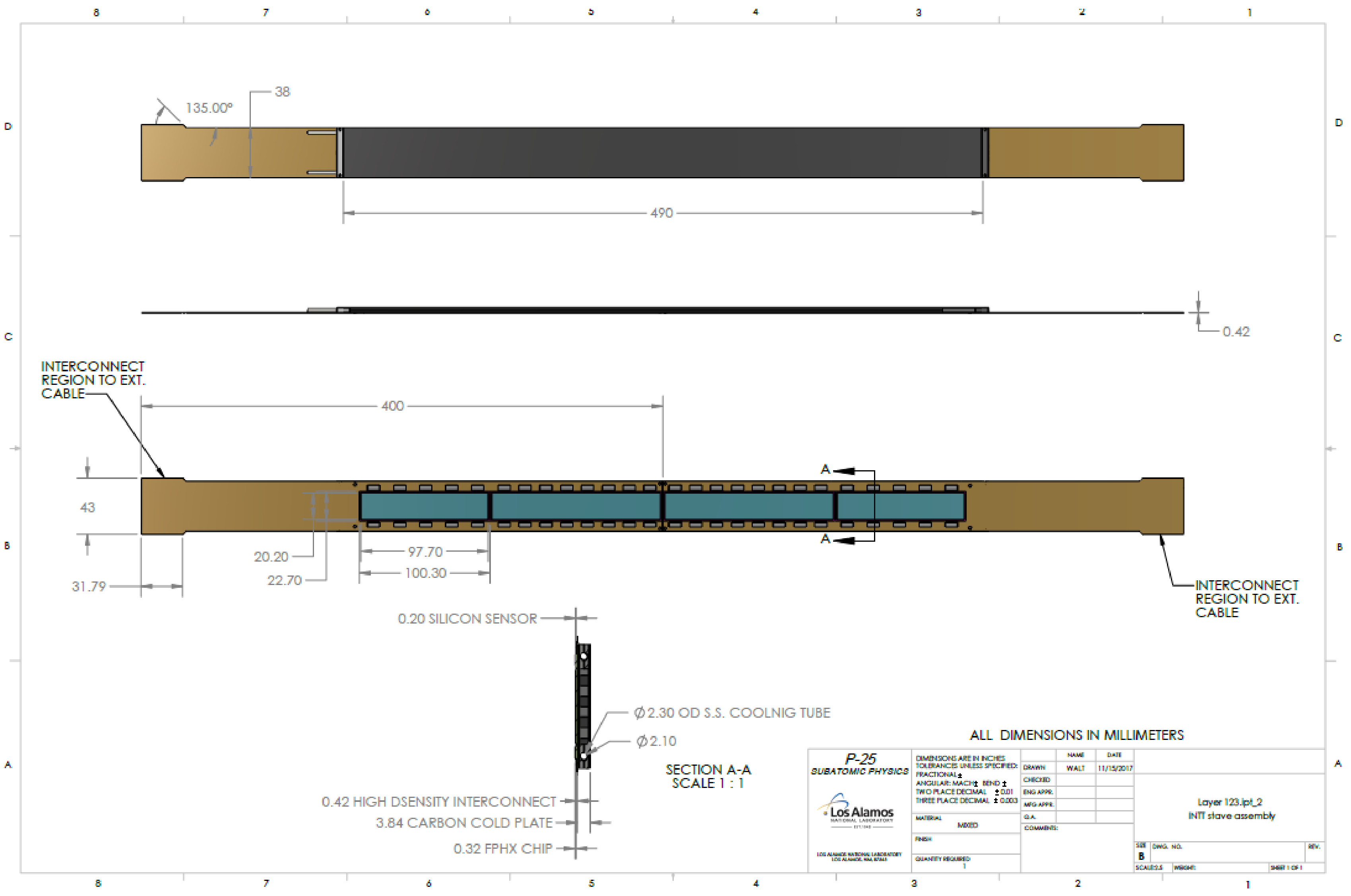
New gap
2.025 mm



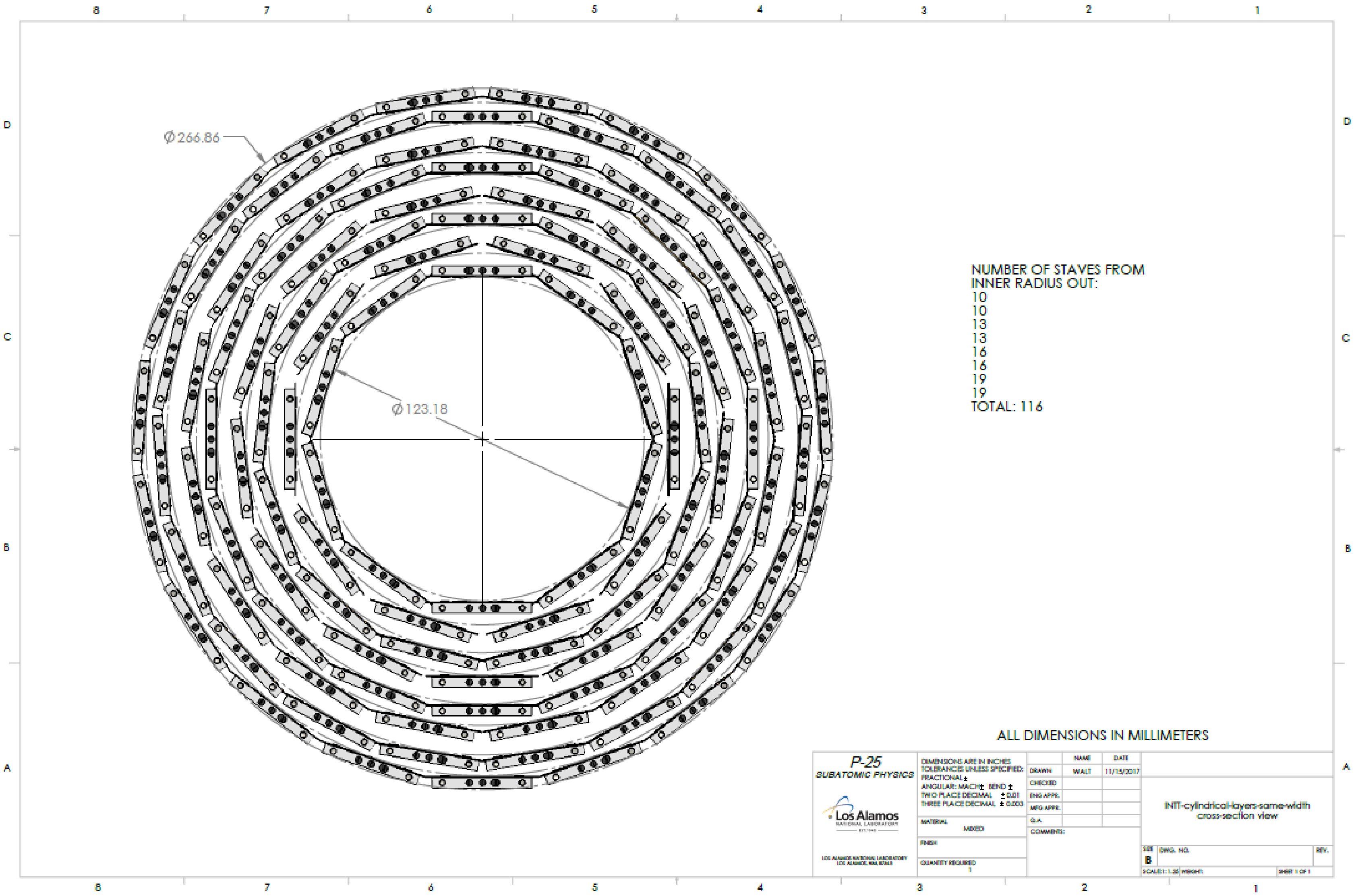
Offset needed to install split MVTX into run location around beampipe, passing over 2.75 in conflat flange



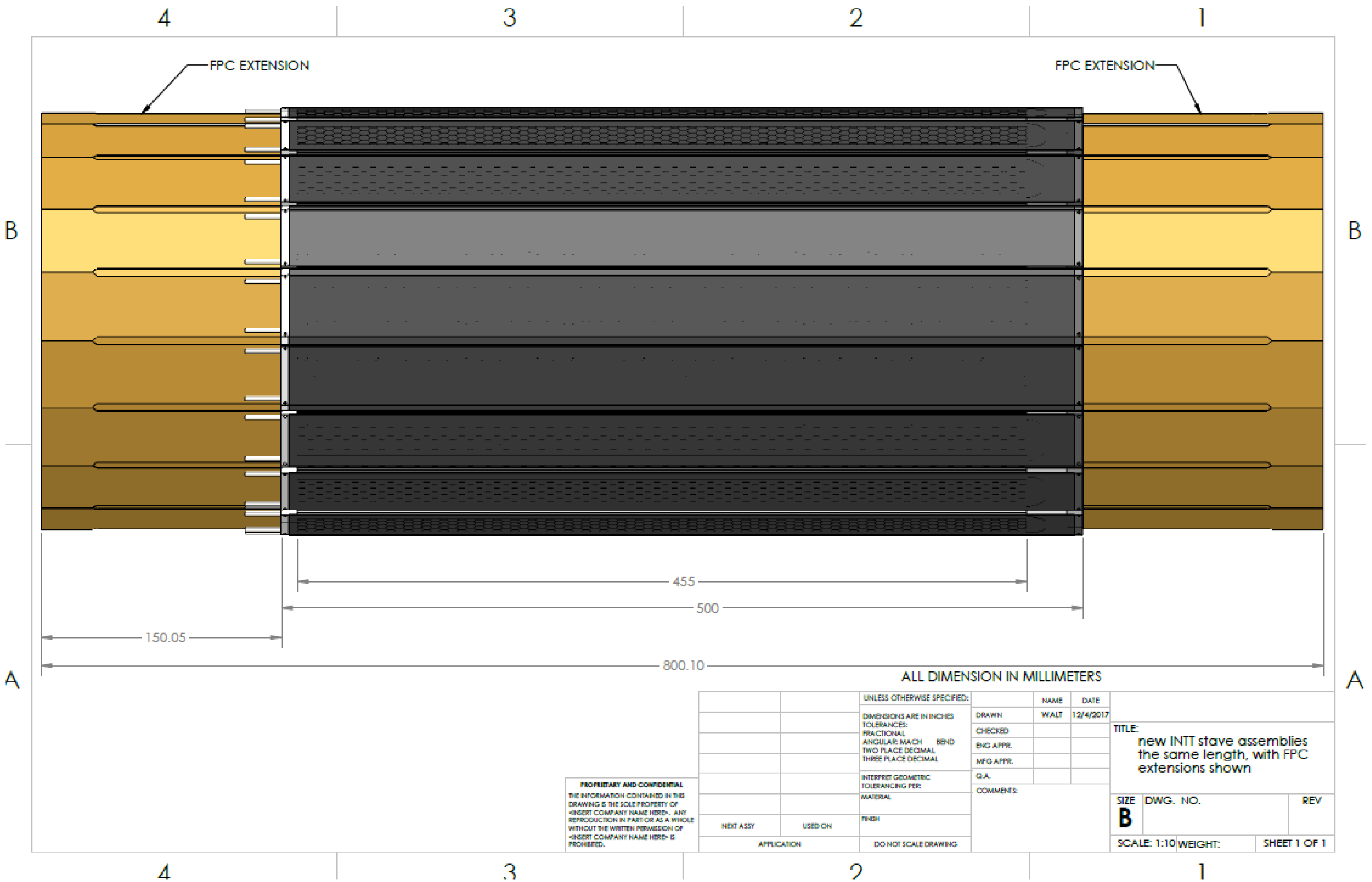
INTT stave design with HDI



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



New INTT model with HDI extensions;



Some High Level Summary of Specs and Deliverables for MVTX

to be added to the proposal

STAR HFT Parameters

High-level CD-4 key performance parameters: instrument must be capable of:

Pointing resolution of HFT system (750 MeV/c kaons)	$\leq$50 μm sPHENIX:<50 um, w/ 2-layer hits requriement
Single-track efficiency for HFT system (1 GeV/c pions)	$\geq$ 60% sPHENIX: >60%
Compatible with STAR DAQ-1000 system	sPHENIX: 15kHz readout

Low-level CD-4 key performance parameters: experimentally demonstrated at Project Completion:

1	Thickness of first PXL layer	< 0.6% X_0	sPHENIX: <0.5%X0
2	Internal alignment and stability PXL	< 30 μm	
3	Internal alignment IST and SSD	< 300 μm	sPHENIX: internal alignment MVTX/INTT
4	PXL integration time	< 200 μs	sPHENIX: <20uS
5	Detector hit efficiency PXL	> 95% sensor efficiency and noise from all sources < 10^{-4}	
6	~~Detector hit efficiency IST~~	~~> 96% with 98% purity~~	
7	Live channels for PXL and IST	> 95%	sPHENIX: use ALICE QA? 90%??-→80% seems OK
8	PXL and IST Readout speed and dead time	<5% additional dead time @ 500 Hz average trigger rate and simulated occupancy	sPHENIX: <5% additional dead time @15kHz
9	~~SSD dead time~~	~~< 9% at 500 Hz~~	

Table 3-1 HFT Key Technical Performance Parameters

3.3.2 CD-4 DELIVERABLES

The HFT MIE project will be complete when all DOE deliverables (Table 3-2) have been tested and installed into the STAR detector at BNL.

Sub-system	Deliverable
PXL	
	PXL insertion structure
	PXL insertion tool
	10 sectors with each sector consisting of : One ladder at a radius of 2.5cm and 3 ladders at 8.0 cm. Each ladder contains: 10 silicon detector elements, one readout board 40 ladders total
	3 DAQ receiver Personnel Computers
	Two clam shells, with five sectors integrated and aligned on each clam shell, installed on pixel insertion tool.
	Forty tested ladders to serve as spares and replacement components to allow for any needed repairs to the existing sectors of the PXL detectors
	Low Voltage, Cabling, and Cooling
	A PC-based control and monitoring system

sPHENIX: mechanical interface structure and tools to sPHENIX Global Rail System

sPHENIX: 3-Layer MVTX

sPHENIX: 6 DAQ PC, hosting 6 FELIX boards

sPHENIX: 3-Layer MVTX, two clam shells

sPHENIX:48 + (28 + 8 spares) = 84

Software	
	Online control software verification

Table 3-2 HFT Deliverables