MVTX Status Overview
WBS 3.2

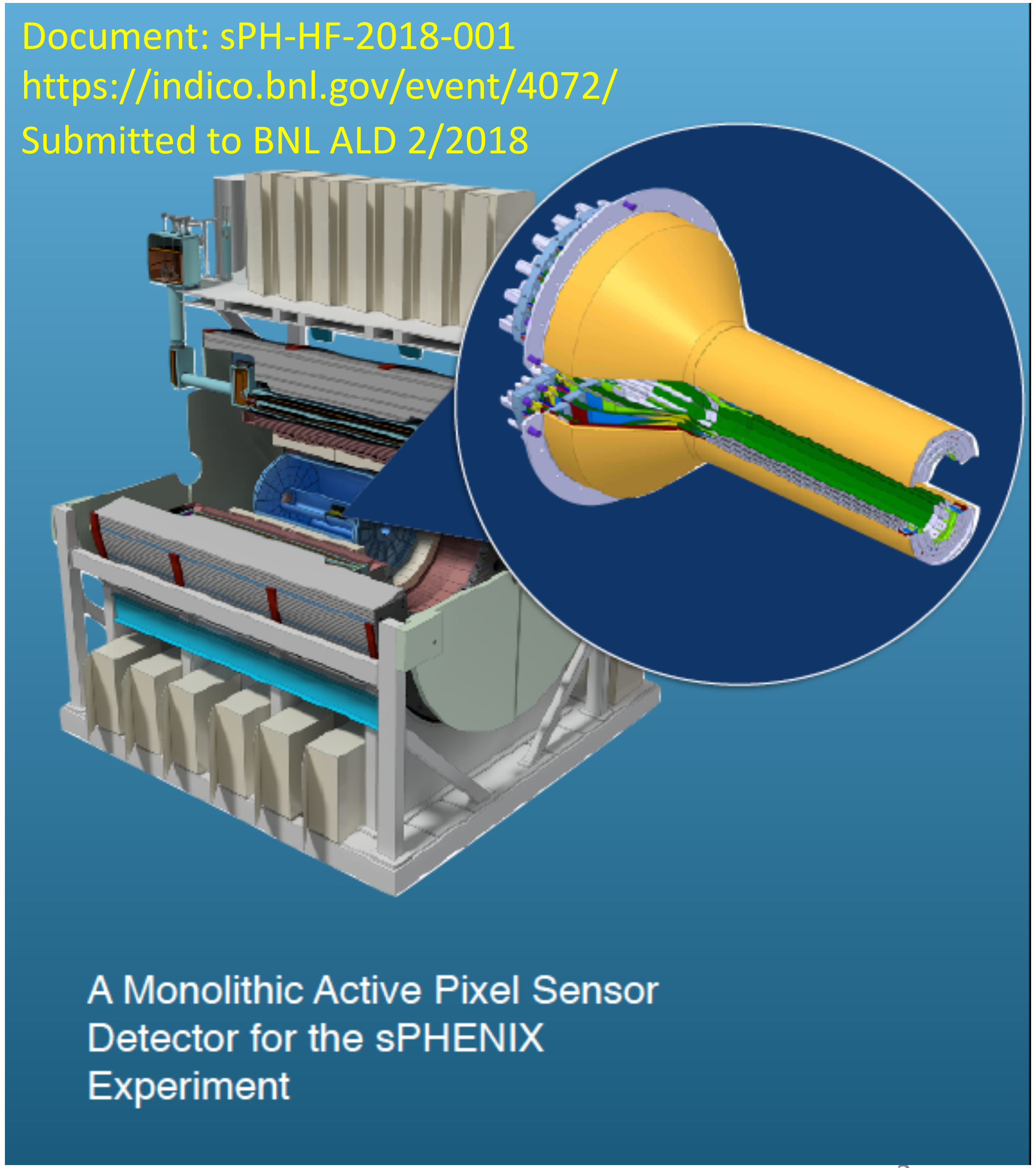
Ming Liu

LANL

For the MVTX Group

Outline

- MVTX project scope update
- Design and R&D progress
- Near term plan

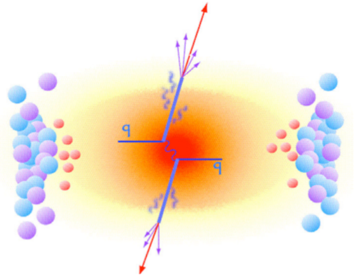


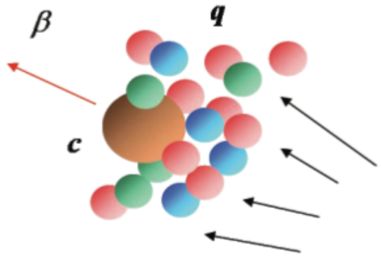
MVTX Enables the 3rd Science Pillar

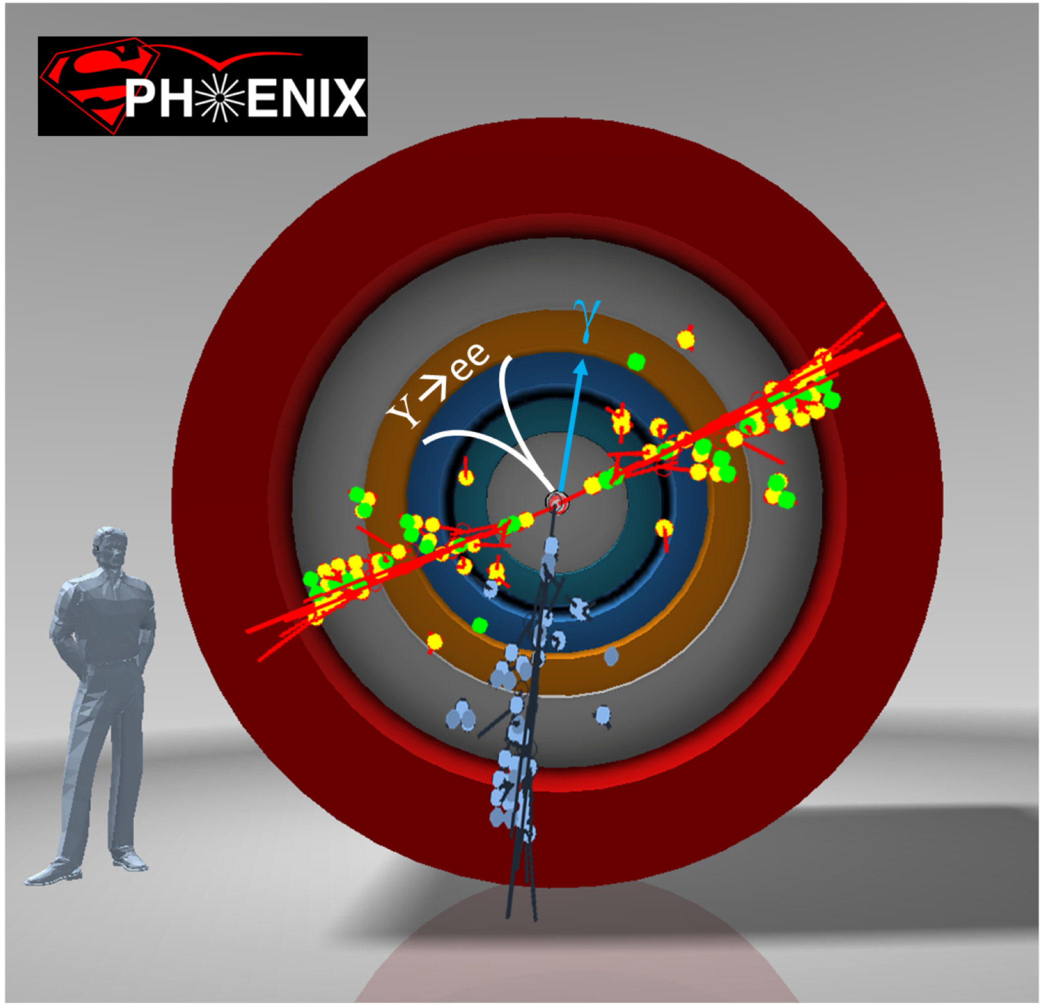
Jin/Xin's talk

1. Jets
2. Upsilons
3. Open Heavy Flavor

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







A Short Summary of the Project Status

- RU and Stave production – a separate direct procurement from ALICE/CERN
  - Technical doc and paperwork were prepared and sent to UTK from BNL in November
  - Paperwork in progress through OSP at UTK, aim for sign-off by December.
    - 60 RUs and 84 staves, production starts ~ January 2019.

- MVTX upgrade project in sPHENIX P6
  - RU and stave production moved out from this scope
  - Work in progress on funding details
    - Split engineering/tech T&E among LANL, MIT, LBNL, BNL etc.
  - Adjustment in WBS scope (some moved to WBS 2.x) to keep the total cost under $5M
  - To be discussed and updated at this sPHENIX collaboration meeting

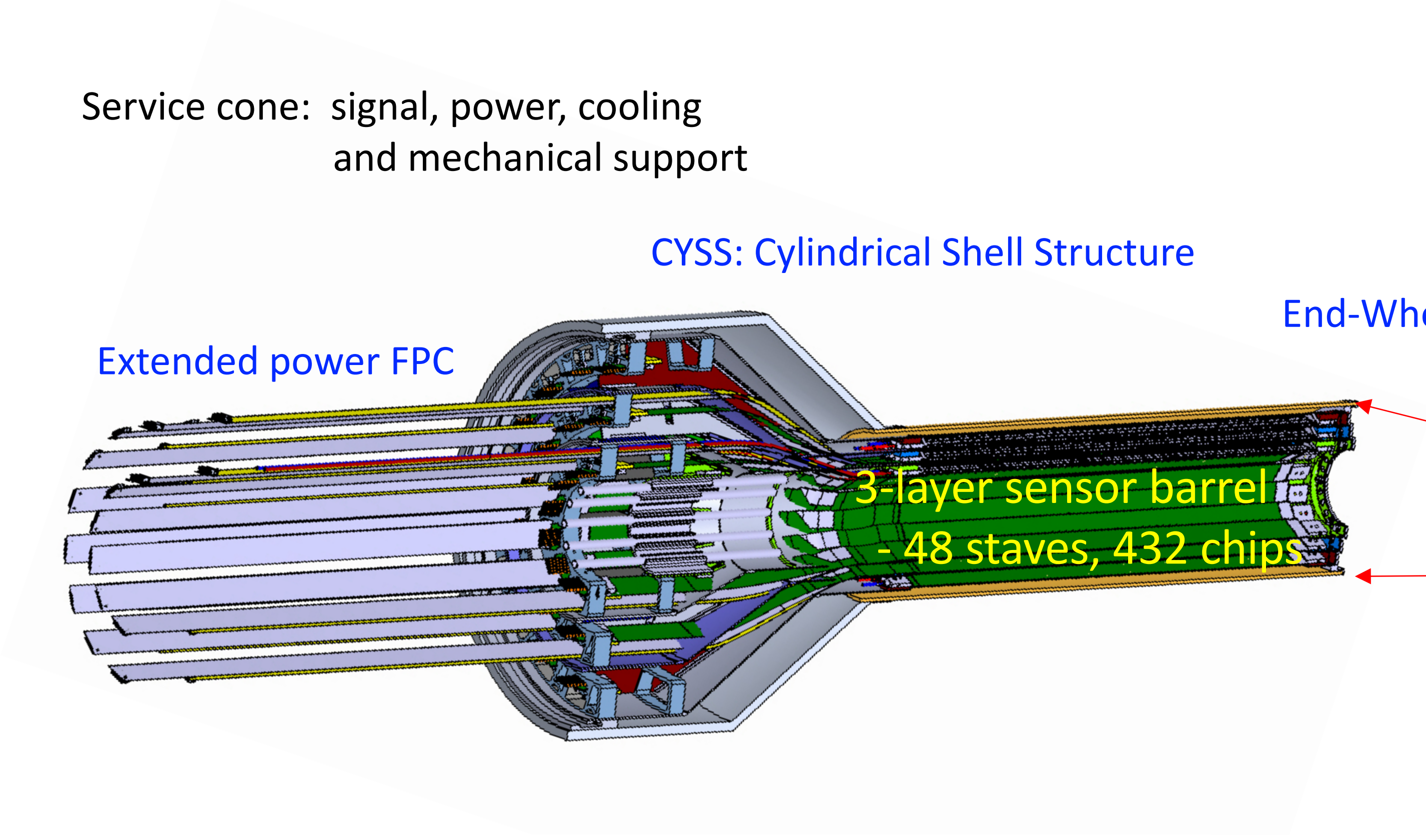
- Recent reviews since last collaboration meeting in June 2018
  - MVTX Production Review 07/19-20, 2018
    - Stave and RU procurement readiness
    - https://indico.bnl.gov/event/4729/
    - Draft responses presented and discussed at PMG meeting
      - Review committee members, BNL and sPHENIX management
  - MVTX Interim Design Review, 11/19/2018
    - Mechanical system integration
    - Led by John Haggerty, draft recommendations being discussed
      - no evident showstoppers
    - https://indico.bnl.gov/event/5351/

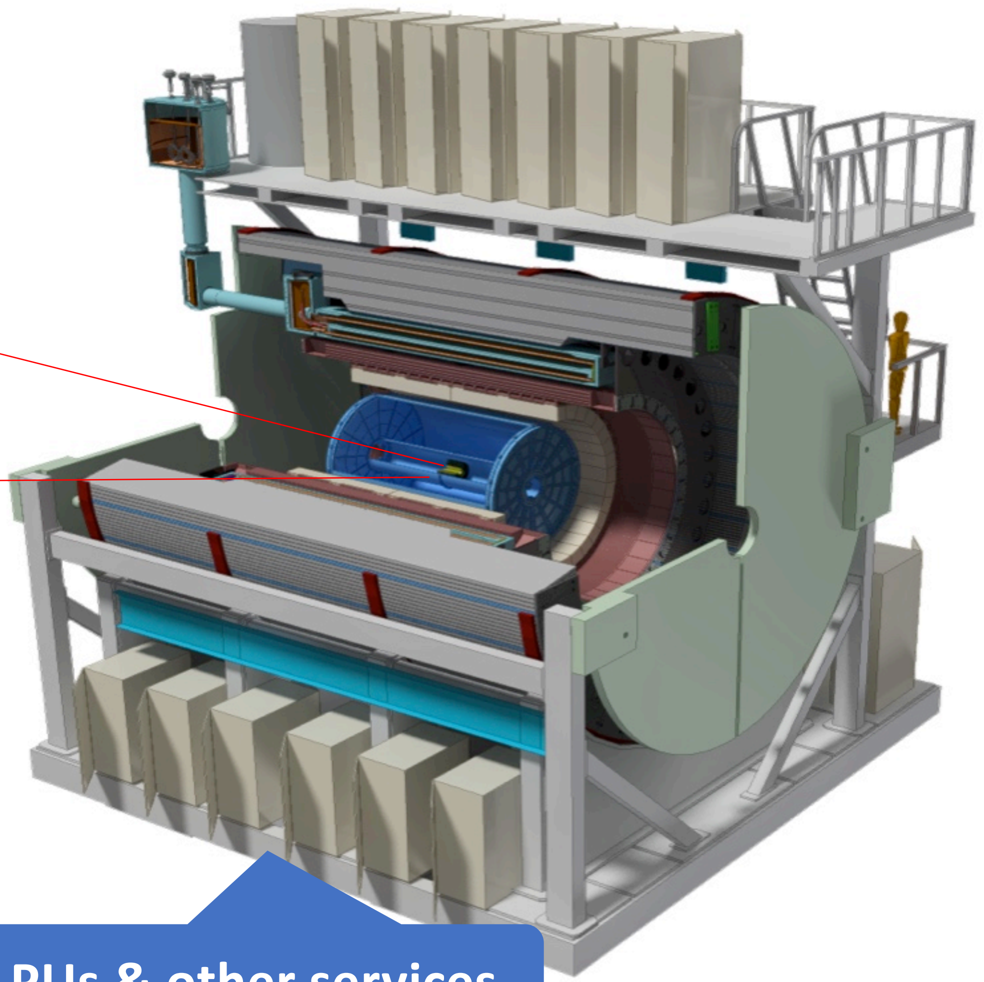
All recommendations on stave/sensor R&D addressed

Recommendations

1. The outline of the step-by-step assembly procedure for the MVTX showing installation of the barrel staves, power cables, and signal cables, should be written down and summarized in one or two slides. This does not have to be the final, more comprehensive assembly procedure, but should show the installation of major components and at what point tests are conducted.
2. The cables to the racks probably need to be longer than 8m, and this should be assessed conservatively.
3. A memo approving the halogenated cables should be on file from the fire protection group.
4. A proposal for extending the beam pipe to move the flanges further from the IP should be discussed with CAD and sPHENIX, as well as beginning a discussion of the beam pipe support.

MVTX Detector

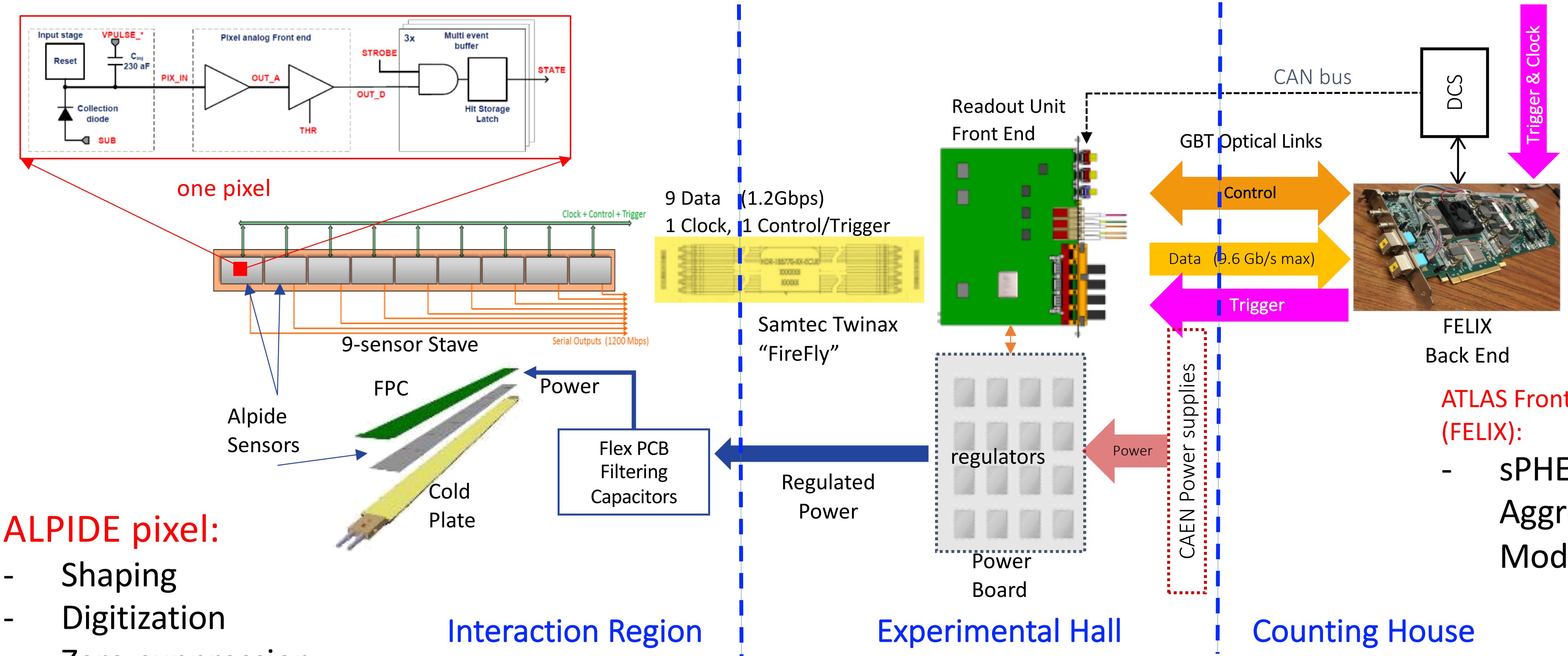




MVTX parameters

	Layer 0	Layer 1	Layer 2
Radial position (min.) (mm)	23.7	31.4	39.1
Radial position (max.) (mm)	28.0	35.9	43.4
Length (sensitive area) (mm)	271	271	271
Active area (cm^2)	421	562	702
Number of pixel chips	108	144	180
Number of staves	12	16	20

MVTX Readout, Power and Controls (11/2018)



ATLAS Front-End Link eXchange (FELIX):

- sPHENIX Data Aggregation Module(DAM)

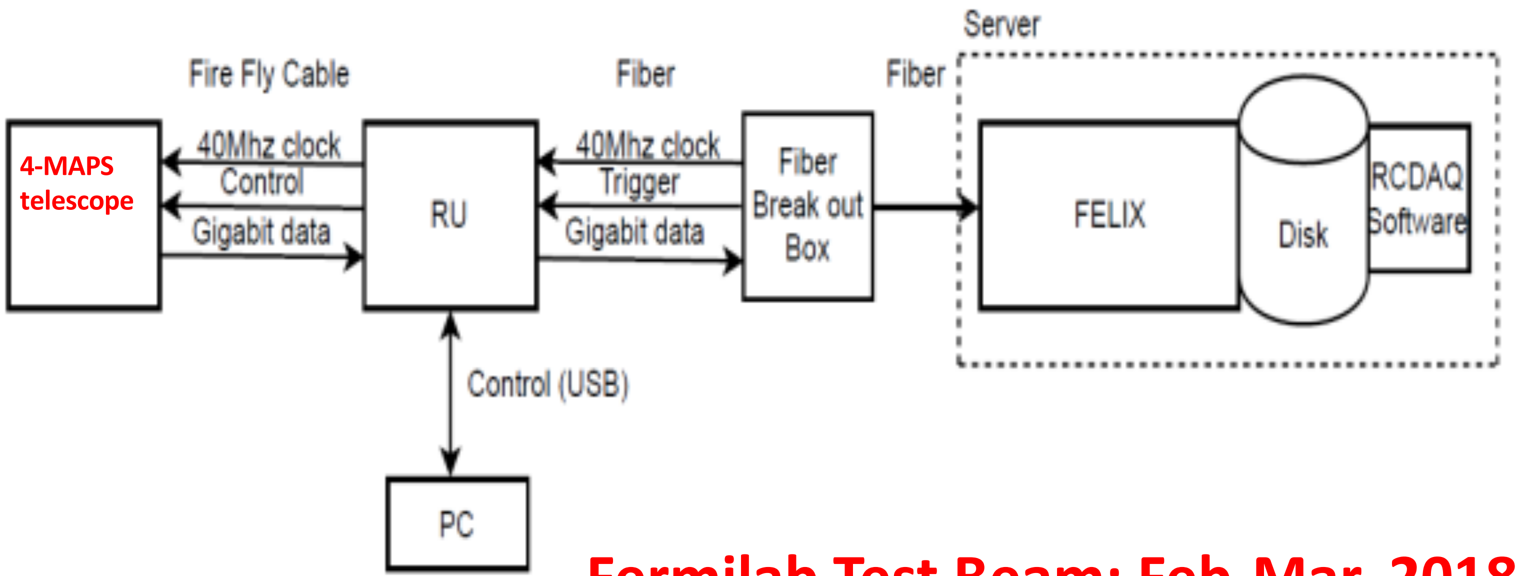
ALPIDE pixel:

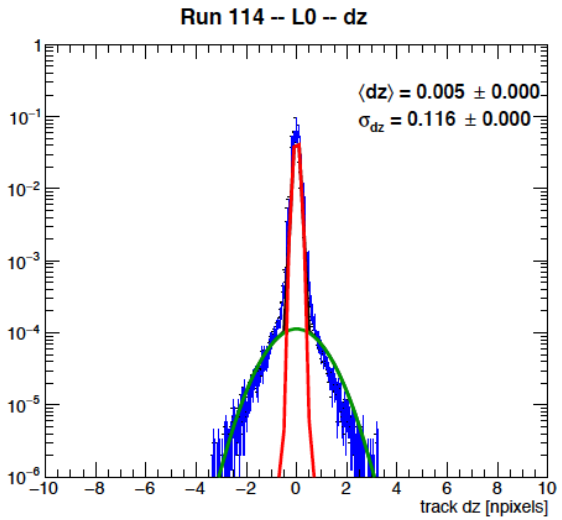
- Shaping
- Digitization
- Zero-suppression
- 3x buffer

MVTX Detector Electronics consists of three parts

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

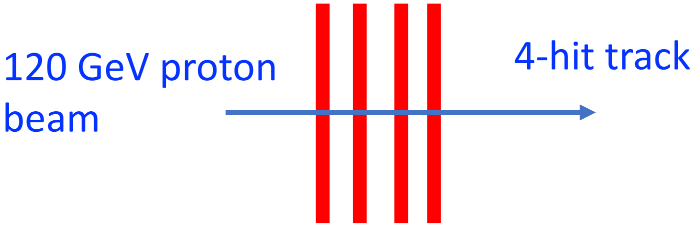
MVTX Full Readout Chain Demonstrated





Tracking spatial resolution achieved: <5 um

Fermilab Test Beam: Feb-Mar, 2018

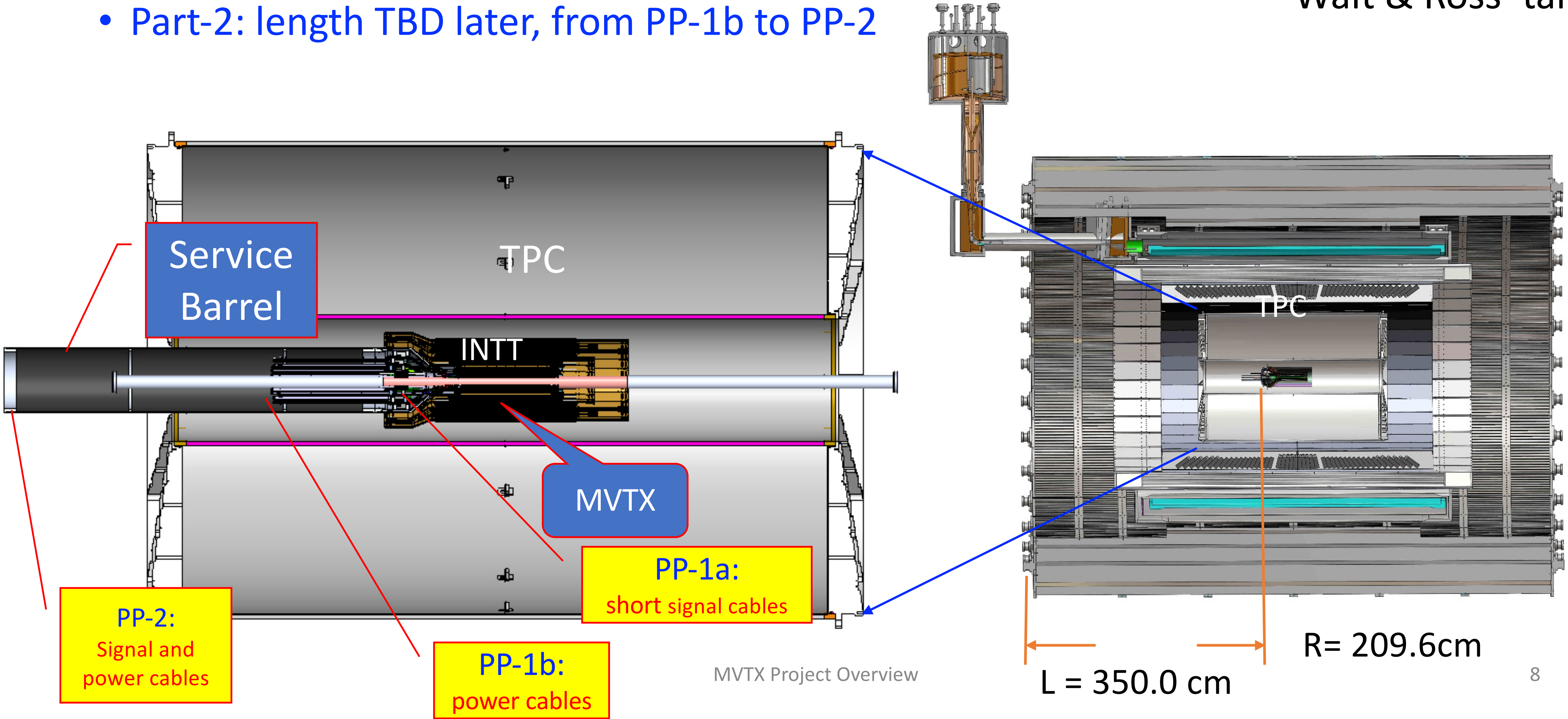


4-MAPS telescope

Progress in MVTX Global Mechanical System Integration

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

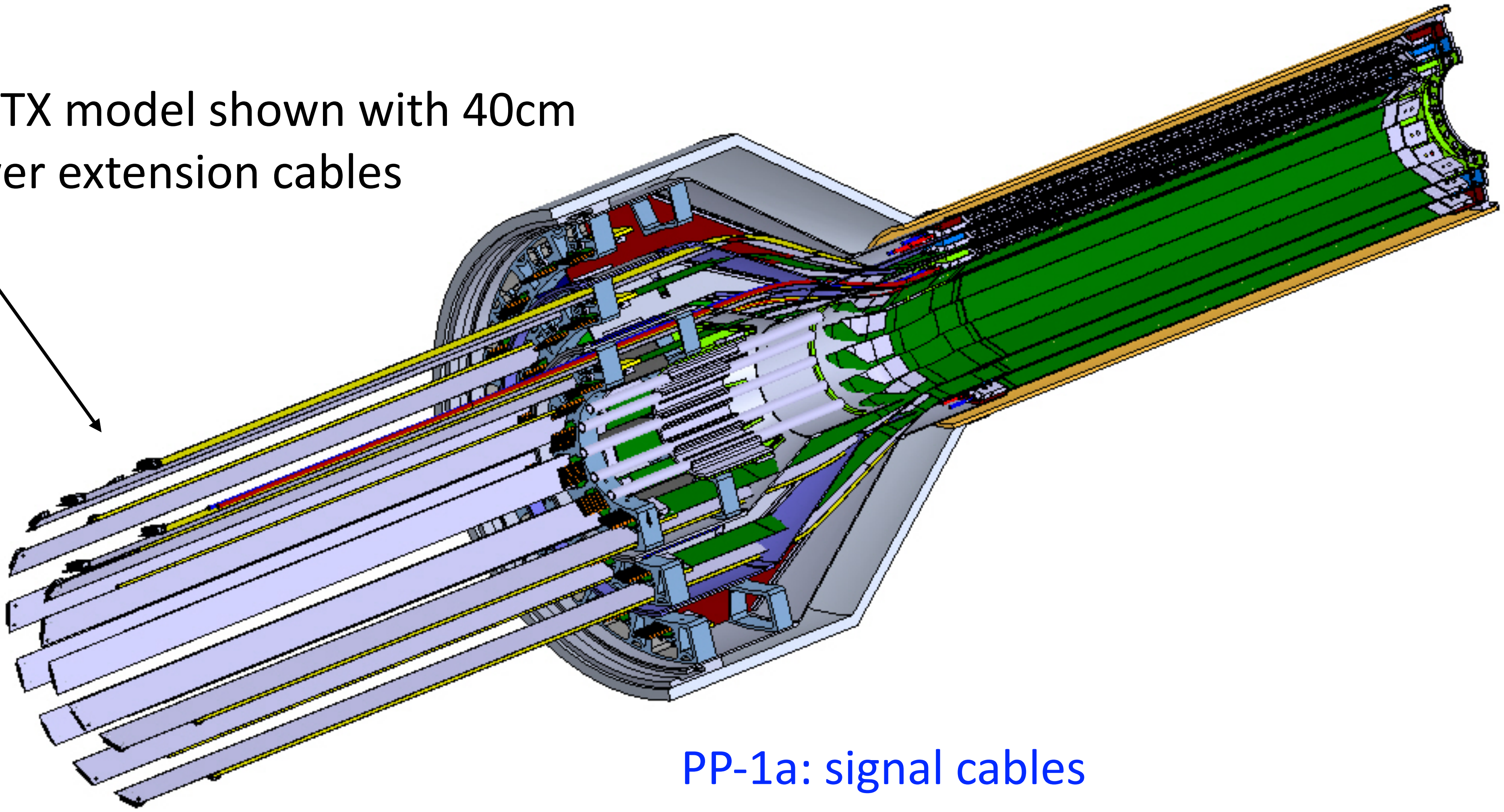
Walt & Ross' talks



MVTX Mechanical Integration in Progress

Walt's talk

This MVTX model shown with 40cm flat power extension cables

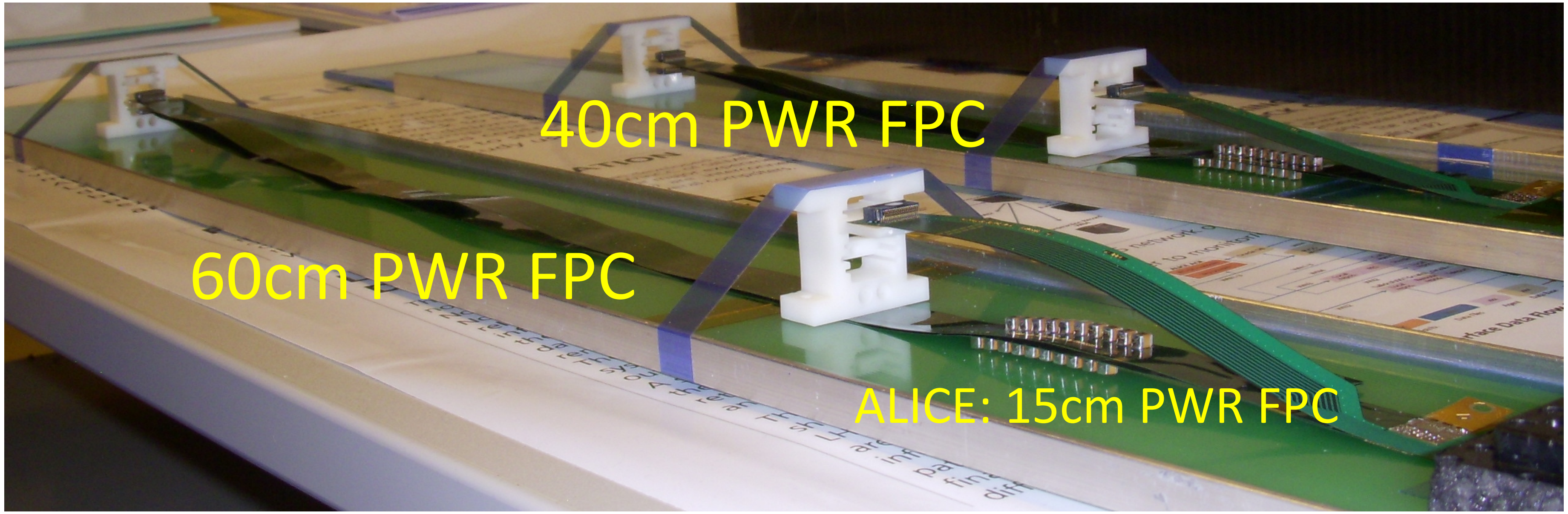


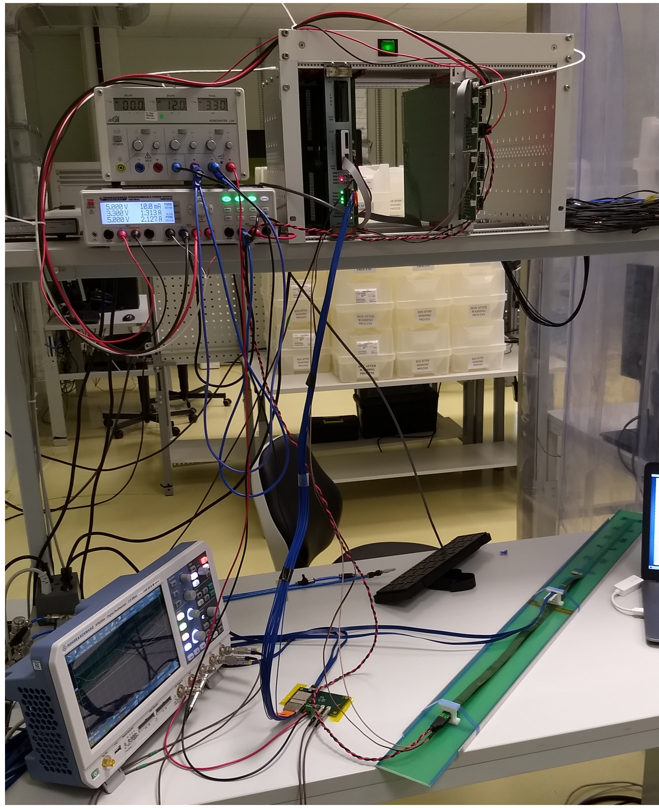
PP-1a: signal cables

PP-1b: power cables

Confirmed HIC with Extended 40(60)cm Power FPC

- Built and tested two HICs at CERN in the week of 9/17/2018
  - No change in sensor performance (noise, threshold) observed, as expected;



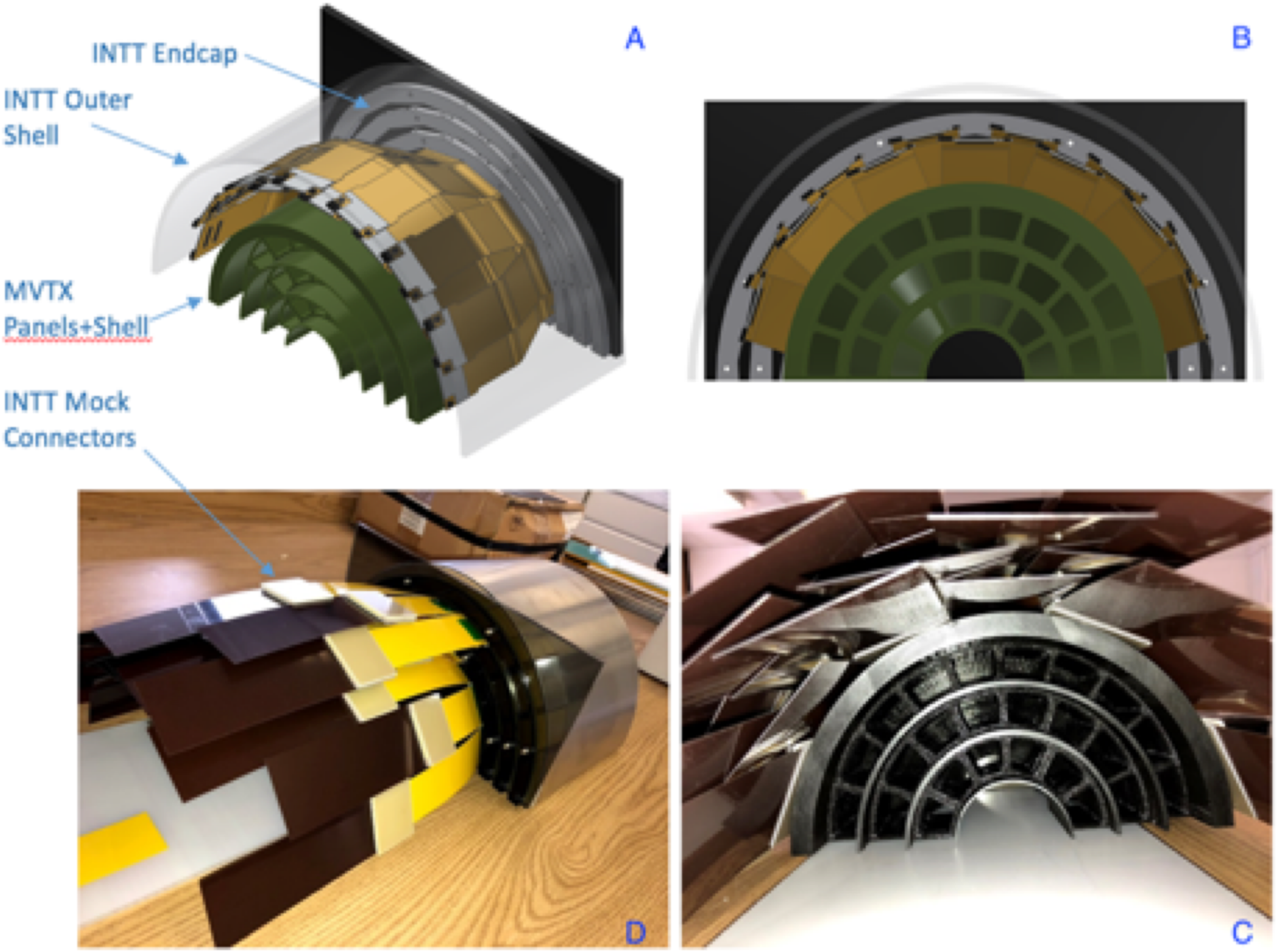


Details presented by Dr. Sho Uemura at the sPHENIX general meeting on 9/23/2018

Nice work by Alex and Sho!

Followed identical ALICE IB QA test procedure, with a 8m SamTec cable!

MVTX + 4-layer INTT 3-D Mockup Demonstrated



Office of System Integration
– led by Mickey & Bob,
a team of engineers and physicists

MVTX and INTT
Space conflict resolved!

Sensor Irradiation Test – OK at 2.7MRad

- Continuous effort by ALICE (@NPI, Czech)
- BNL review recommendation: test sensor up to 1MRad

https://indico.cern.ch/event/758048/

Conclusion

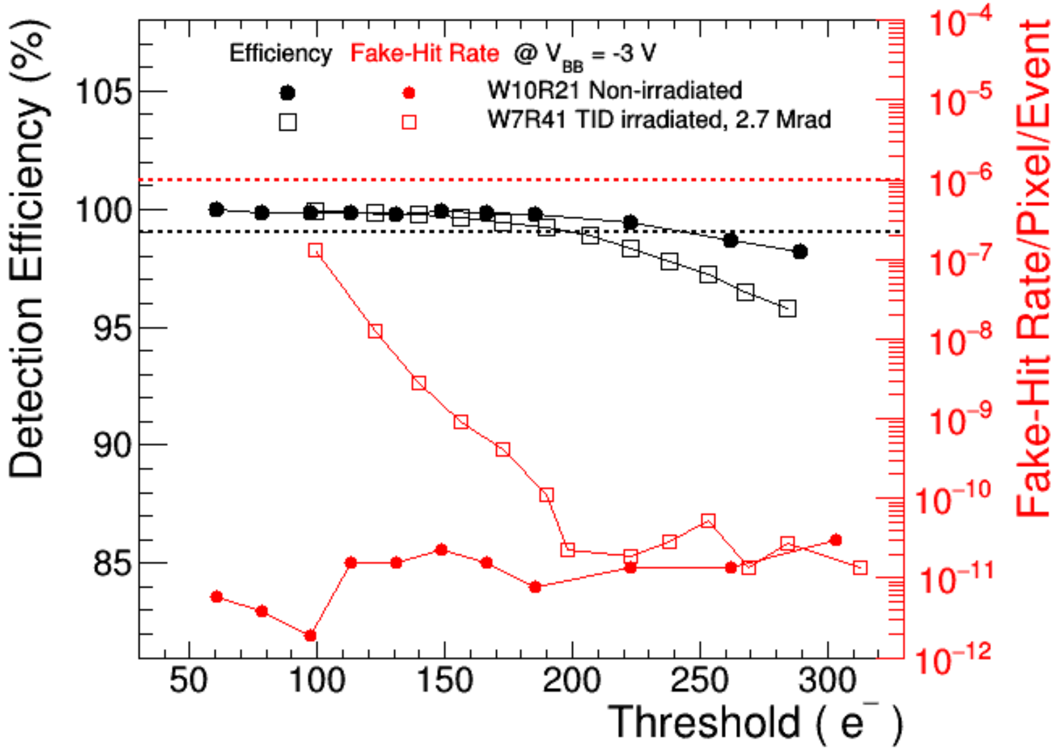
Irradiated ALPIDE sensor (2700 krad) over a large range of threshold settings

has :

1) good efficiency up to threshold ~190 e (Ithr = 100 DAC units)
at Vbb = - 3 V, Vcasn = 90, Vcasn2 = 102

2) fake hit rate remains orders of magnitude
smaller than the requirement (<< 10^{-6})

Irradiated chip#41 (2.7Mrad) : efficiency & fake hit rate



red line - fake hit rate- sensitivity limit of ALPIDE
black line - efficiency - the project goal (99%)

For non irradiated 2 noisy pixels were masked out.
No pixel was masked out for the 2.7Mrad chip.

Response to the July MVTX Review Recommendations

https://docs.google.com/document/d/1vsm_G7ZLgqv-kBZqK0jF69T_Nx2Uwk0Zxv86jRVxybw/edit?usp=sharing

- Completed sensor/HIC/stave evaluations at CERN
  - Built and tested two HICs with 40cm and 60cm long power FPC
    - Confirmed sensor performance same as the ALICE default configuration
  - Sensors irradiated up to 2.7MRad, no problem (updated 9/18/2018).

Addressed all recommendations on stave/sensor R&D

- Cost are set for staves/RU, UTK has started procurement paperwork
  - Technical specs document completed for production
  - RU, Staves, sPHENIX production starts ~ January 2019, expect to last ~12 months
- MVTX/INTT mechanical integration
  - Mechanical design being updated and mockup done
  - Inner tracking task force completed evaluation, preferred INTT-layer < 4
  - SamTec readout cables
    - ALICE confirmed signal performance with 8m long readout cables. For MVTX, 10m very likely works (30AWG vs 32AWG), to be confirmed by on-going R&D
- Cables
  - BNL approved the use of SamTec blue cables
    - Electrically better & mechanically compact
  - Signal and power cable samples ordered/obtained for mechanical global system integration mockup

Scope of the MVTX Project

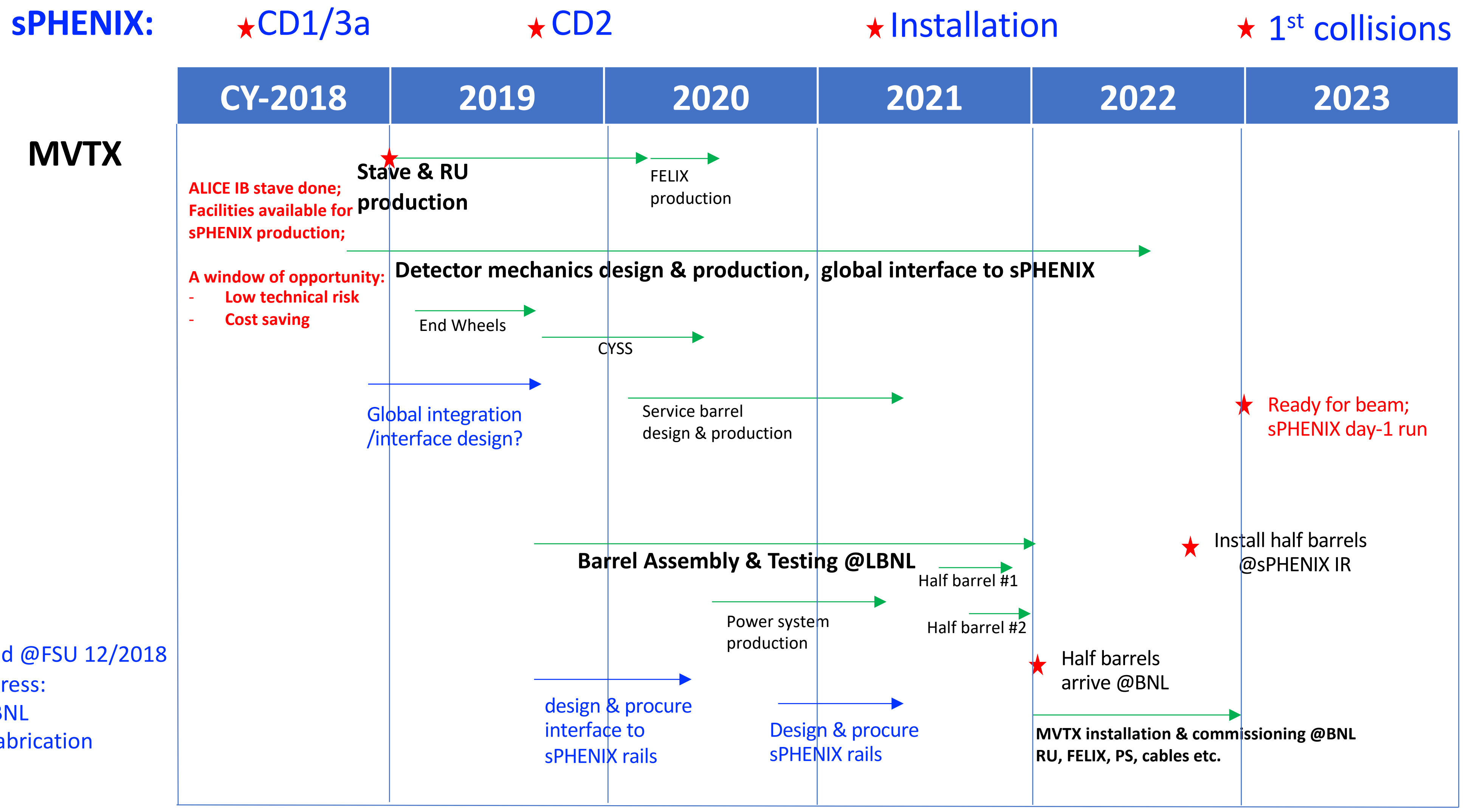
Dave's talk

- MAPS Staves & Electronics
  - Readout Integration R&D (LANL LDRD)
    - Frontend: ALICE/ITS, RU
    - Backend: ATLAS FELIX
    - Reprogram RU & FELIX into RCDAQ/sPHENIX
  - Production-I:
    - **84 ALICE/ITS-IB staves from CERN**
      - Acceptance test @LBNL, 48+spares(36)
    - **60 ALICE/ITS-RU from CERN**
      - Acceptance test @UT-Austin, 48+spares(10)
  - Production-II:
    - sPHENIX production
      - Acceptance test @LANL, 8 FELIX
    - Final detector assembly in US
      - LBNL half detectors
      - BNL full detector
    - Ancillary systems
      - "adopt" ALICE ITS system
      - Power, slow control & monitoring etc.

- Mechanics & Cooling
  - Changes to ALICE/ITS inner tracker mechanical structures
    - End Wheels
    - Cylindrical structure shells
    - Detector half barrels
    - Detector and Service half barrels
  - Mechanical Integration,
    - Conceptual design (LANL LDRD)
    - Prototyping sPHENIX R&D
    - Design integration frames, MIT/LANL/LBNL
    - Composite structures, LBNL
    - Non-composite structure, MIT
    - Installation tooling etc., BNL/LANL/MIT/LBNL
  - Adopt ALICE cooling plant design
    - Modifications to fit sPHENIX, MIT/BNL
    - Much smaller heat load than ALICE ITS

MVTX Schedules and Milestones (11/2018)

Dave's talk



To be updated @FSU 12/2018
Work in progress:
LANL/MIT/LBNL
Design and fabrication

Stave and RU Production QA Plan Documents

https://indico.bnl.gov/event/4729/

Staves

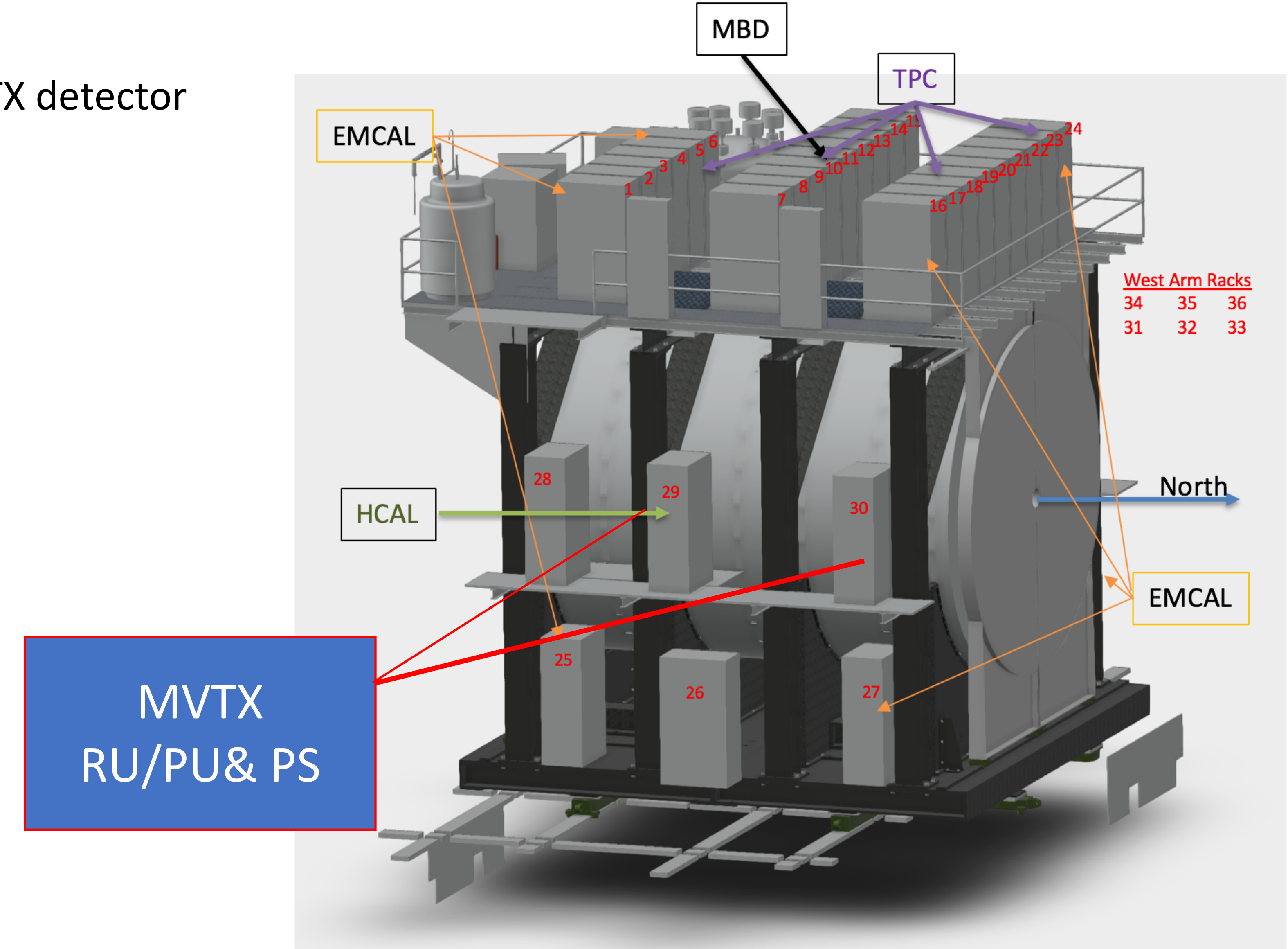
- Purchase 84 staves from ALICE/CERN
  - 48 + 28(spares for 2 inner layers) + 8 spares
  - Production following the completion of ALICE ITS/IB
  - Starting ~Oct. 2018, will last 6-12 months
  - Fully tested at CERN before shipping to US
    - All Gold/Silver staves (same as ALICE IB)
    - A LANL postdoc (Dr. Yasser Morales) oversees production QA at CERN
- Acceptance QA at LBNL
  - Full test and QA
    - Electrical
    - Mechanical
  - Detector assembly at LBNL

Readout Units

- Purchase 60 RUs from ALICE/CERN
  - 48 + 12 spares(20%)
  - To be part of ALICE production
    - Cost saving
    - Minimize technical risks
  - Initial test at CERN
- Acceptance QA at UT-Austin
  - Full test
  - LANL as the 2nd test site

MVTX Services - Work in Progress

- Service racks located close to MVTX detector
  - RU
  - PU
  - "Minimal cable length", ~8m
    - R&D on 10m at LANL
- 48 RU and 24 PU
  - 1PU ->2RU
  - 6-U VME crates
- CAEN bulk power supply
  - located nearby
- Cooling plant
  - Location TBD



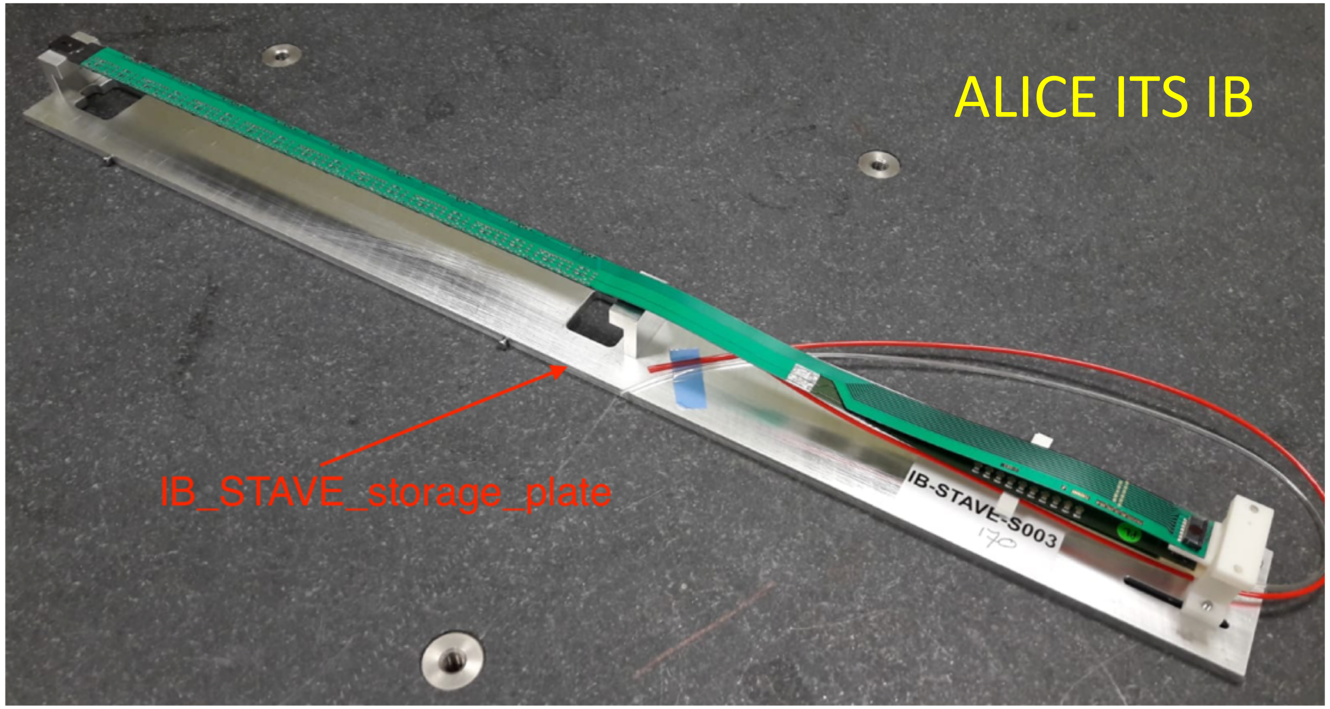
Near Term Project Tasks & Schedule

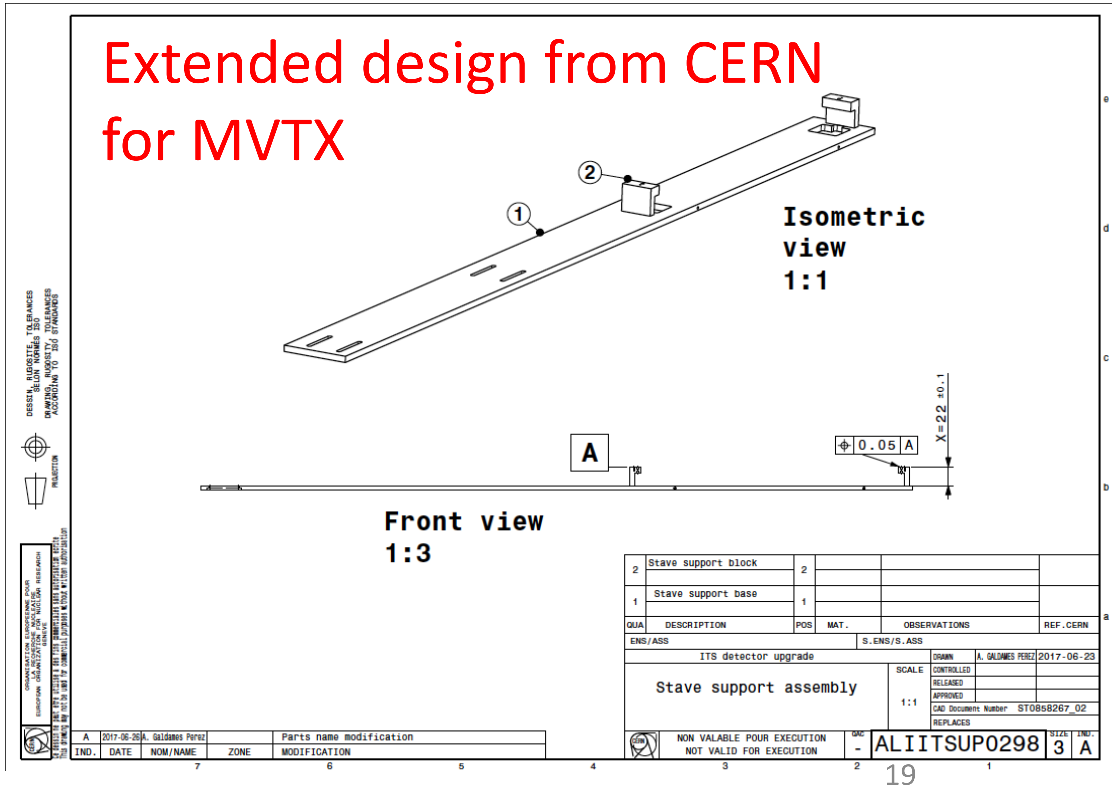
- RU production through ALICE: 60 RUs
  - Being started at CERN, first batch of ALICE production ~ Dec., 2018
    - sPHENIX RUs available: ~Summer 2019
  - Acceptance test and QA at UT-Austin: starting ~summer 2019
    - Good opportunity for training and contribution
- Stave production through ALICE: 84 staves (ALICE Gold/Silver QA)
  - sPHENIX sensor production ~Jan. 2019
    - 3 months (wafer production) + 1 month (dicing & testing)
    - Stave assembly starts @CERN, ~ April 2019, will take ~12 months to finish
    - Training & contribution at CERN, Stave test and QA
  - Acceptance test and QA at LBNL, ~Summer 2019
    - Hand-carrying staves to LBNL, ~4 trips, ~20 staves each trip
- Mechanical system integration design
  - In good progress, under OSI
- Carbon and non-composite structure design and fabrication
  - Design & review – LANL/MIT/LBNL
  - Carbon structures fabrication @LBNL
  - Non-composite structure fabrication @MIT
- Half-detector assembly at LBNL
  - To setup assembly & test lab as soon as fund available
- Safety, slow-control and monitoring
- MVTX detector commissioning at BNL
  - Setup lab, pre-installation commissioning
  - IR installation
- Physics & detector simulations, tracking etc.

More discussions in this week

Stave Production and Shipping etc

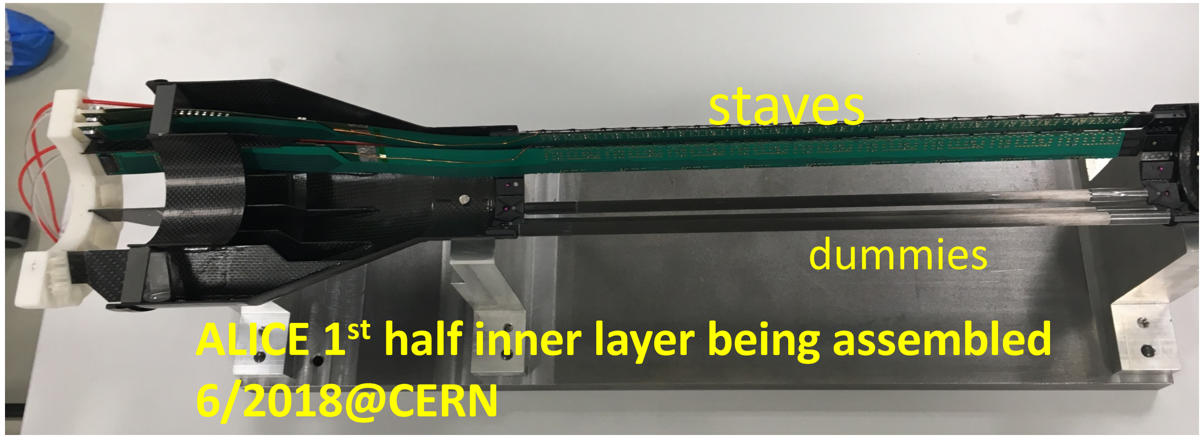
- Hand carry staves from CERN to LBNL, 4 trips
- Preliminary design from CERN for stave transportation plates
  - To be produced at CERN, paid by LBNL/sPHENIX



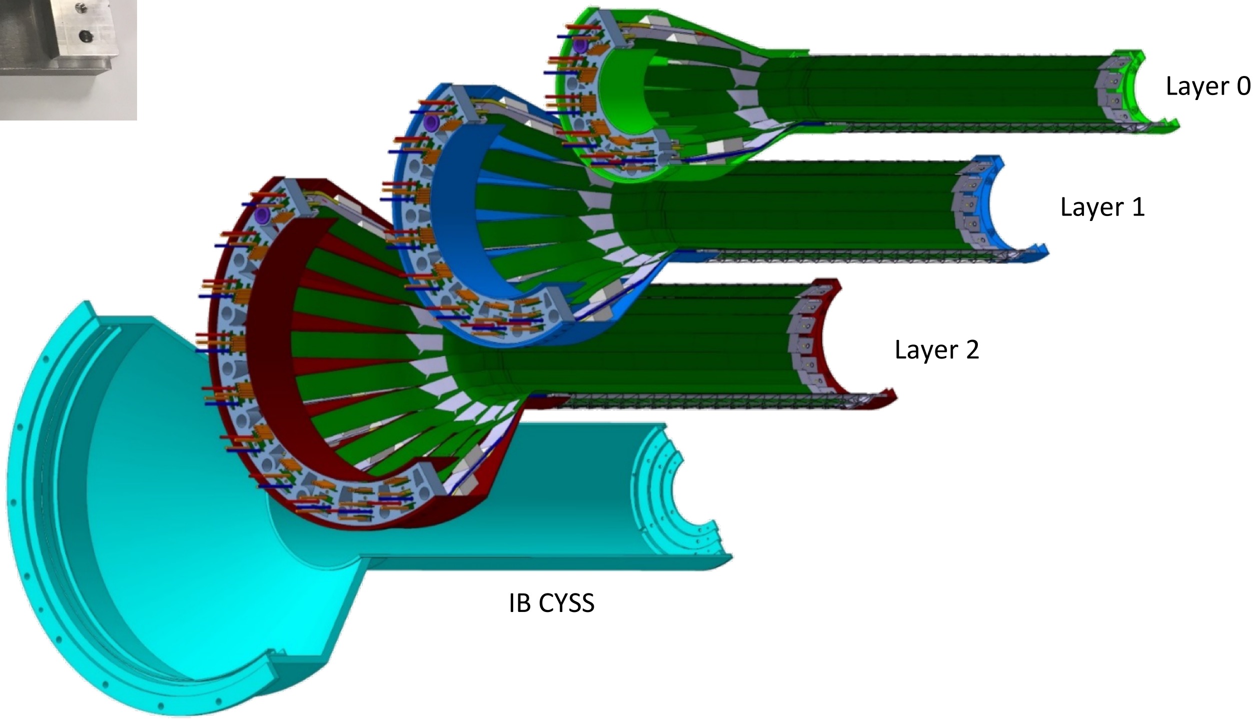


Detector Assembly & QA at LBNL

Walt & Yuan's Talks



Precision positioning and installation of staves on end-wheels



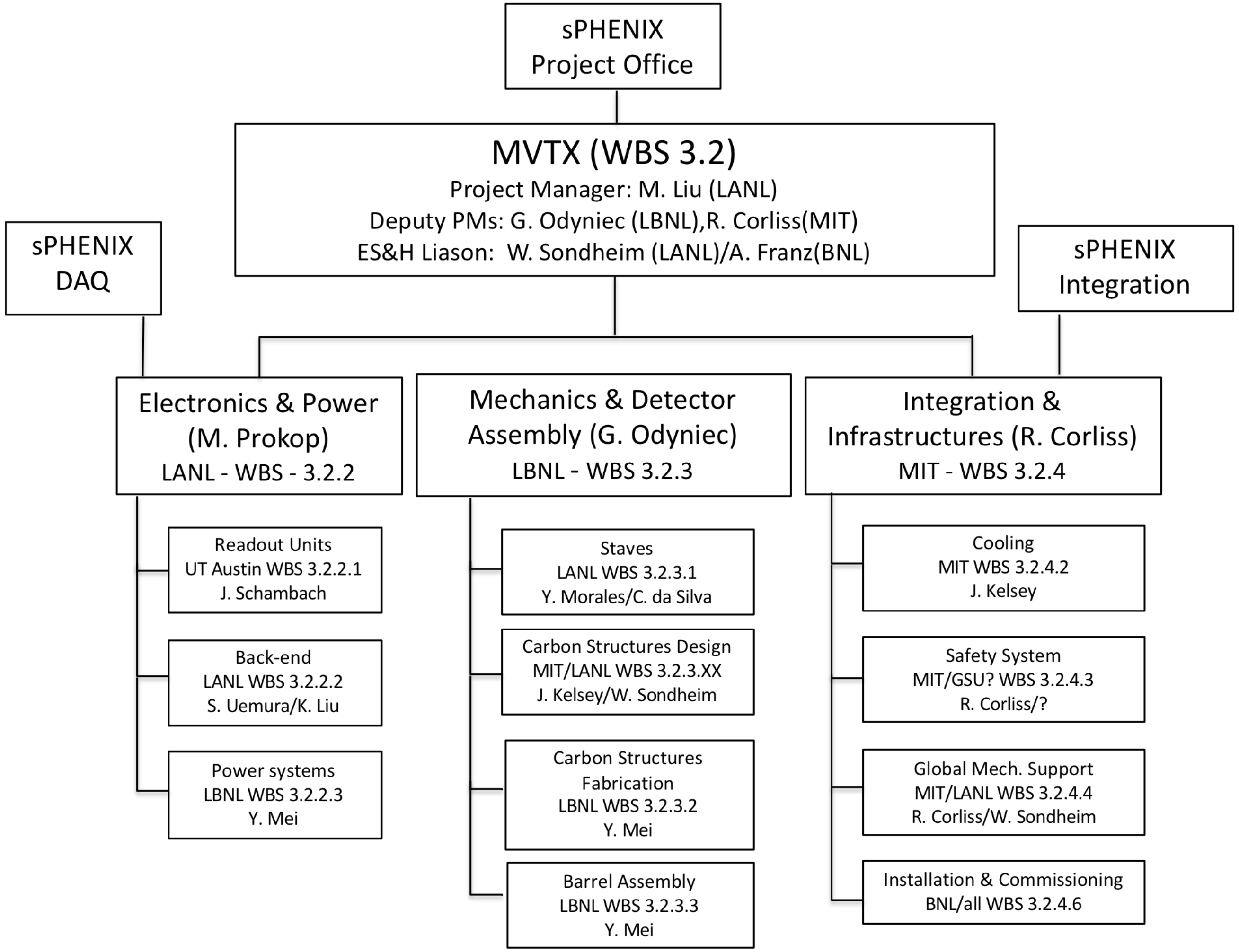
- Follow ALICE IB assembly procedures to build half-detectors for MVTX
- QA records in DB, travelers
- Modified jigs for MVTX
- Build two full half-barrel detector with the service structures

Install SamTec & power cables during half-barrel assembly with the service barrel at LBNL (under discussion)

sPHENIX MVTX Group: Institution Roles

for discussions

- Major institutions lead key tasks



Los Alamos National Laboratory (LANL) : Overall readout electronics and mechanical system integration, project management.

Brookhaven National Laboratory (BNL) : Global system integration and services, safety and monitoring, project management.

Lawrence Berkley National Laboratory (LBNL) : Carbon structure production, LV and HV power system, full detector assembly and test, project management.

Massachusetts Institute of Technology (MIT/Bates) : Global mechanical system integration and cooling.

Massachusetts Institute of Technology (MIT) : Stave assembly and test at CERN.

University of California at Los Angeles (UCLA) : Simulation and readout testing.

University of California at Riverside (UCR) : Detector assembly and test, simulations.

Central China Normal University (CCNU/China): MAPS chip and stave test at CERN and/or CCNU.

Charles University (CU/Czech) : MAPS stave production and QA.

University of Colorado (UCol) : *b*-jet simulations and future hardware.

Czech Technical University (CTU/Czech) : MAPS stave production and QA at CERN.

Florida State University (FSU) : Offline software and simulations.

Georgia State University (GSU) : Online software and trigger development.

Iowa State University (ISU) : Detector assembly and test, simulations.

National Central University (NCU/Taiwan)* : Stave assembly and test, simulations.

University of New Mexico (UNM) : Cabling & connectors.

New Mexico State University (NMSU) : Tracking algorithm and physics simulations.

Purdue University (PU): Detector assembly and test, simulations.

Univ. of Science and Technology of China (USTC/China) : MAPS chip and stave test, simulations.

Sun Yat-Sen University (SYSU/China) : MVTX detector and physics simulations.

University of Texas at Austin (UTA) : MVTX readout electronics integration, Readout Units production and test.

Yonsei University (YSU/Korea) : MAPS chip production QA, readout electronics test and simulations

Other Activities and Plan

- CERN/ALICE visit planned ~end of January 2019
  - Walt, Ming, and MIT/Bolek, Jim, Ross et al
  - Mechanical design and integration
  - Produce 5 staves for MVTX telescope
- Preparation for MVTX stave production at CERN
  - One LANL PD hired at CERN
  - MIT student/postdoc/tech help at CERN, under discussion
  - LBNL will start preparing the MVTX detector lab as soon as funds will transferred
- Fermilab beam test with INTT, ~May 2019
  - Waiting for HDI cables for INTT
  - MVTX telescope will be ready ~March 2019
  - A joint test beam proposal being developed
  - Test global tracking, timing etc.
- Possible MVTX beam test at LBNL
  - MVXT sensor and readout electronics characterization etc.
  - Details under discussion

Summary: MVTX - WBS 3.2

- MS Project being updated, now in the sPHENIX P6
  - Stave and RU production through ALICE, moved out of the scope
  - The rest of tasks, being optimize for cash flow and production schedule

- Early procurements of staves and readout units (RU) through US-Alice
  - DOE and BNL agreed, DOE directly pays UTK/US-ALICE
  - Received signed letter from CERN on the cost of 60 RUs and 84 Stave, ~$1.36M
  - Purchase paperwork in progress at UTK, aiming to complete by ~ December 2018

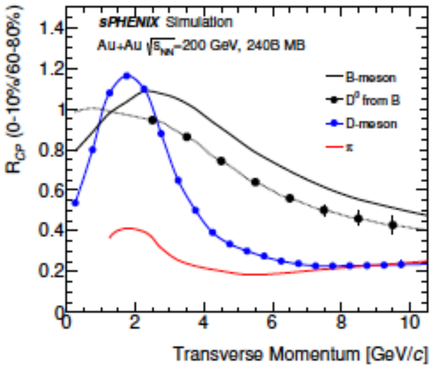
- About $5M to be added to the sPHENIX Management Portfolio
  - Open MVTX accounts in progress
  - As a separated project from the MIE, for the rest of MVTX tasks
    - Mechanical system design and fabrication
    - Monthly report to sPHENIX and BNL upper management
    - Update baseline cost and schedule by January 2019
  - Will NOT be part of CD-2/3 DOE review
    - Prepared for a separate DOE review in FY19

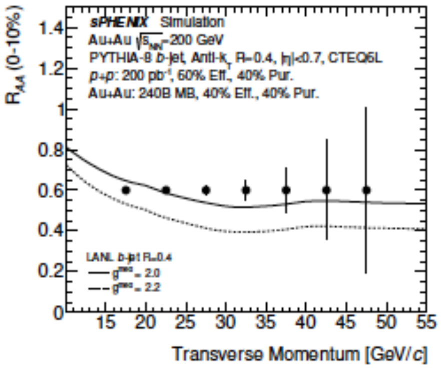
backup

MVTX Physics Highlights

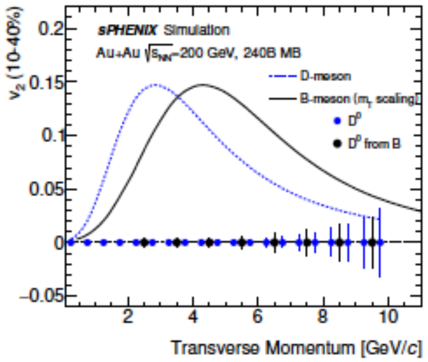
- Heavy quarks – unique probe of QGP w/ new scales, **m_c, m_b**
  - Study mass dependence
    - Jet quenching & energy loss
    - Flow – interaction with medium
  - Access QGP properties
    - Temperature, density, coupling, transport coefficients, viscosity etc.

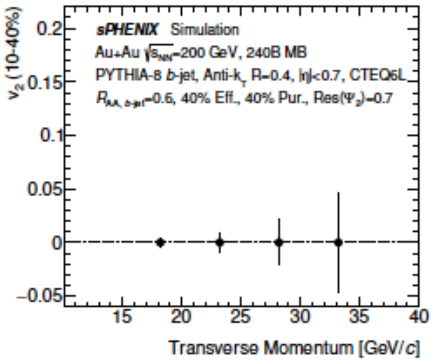
"B meson and b-jet modification"

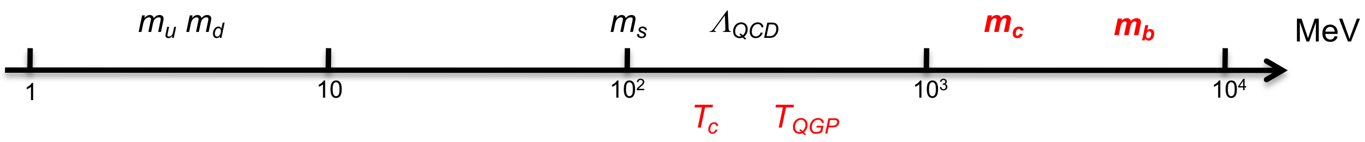


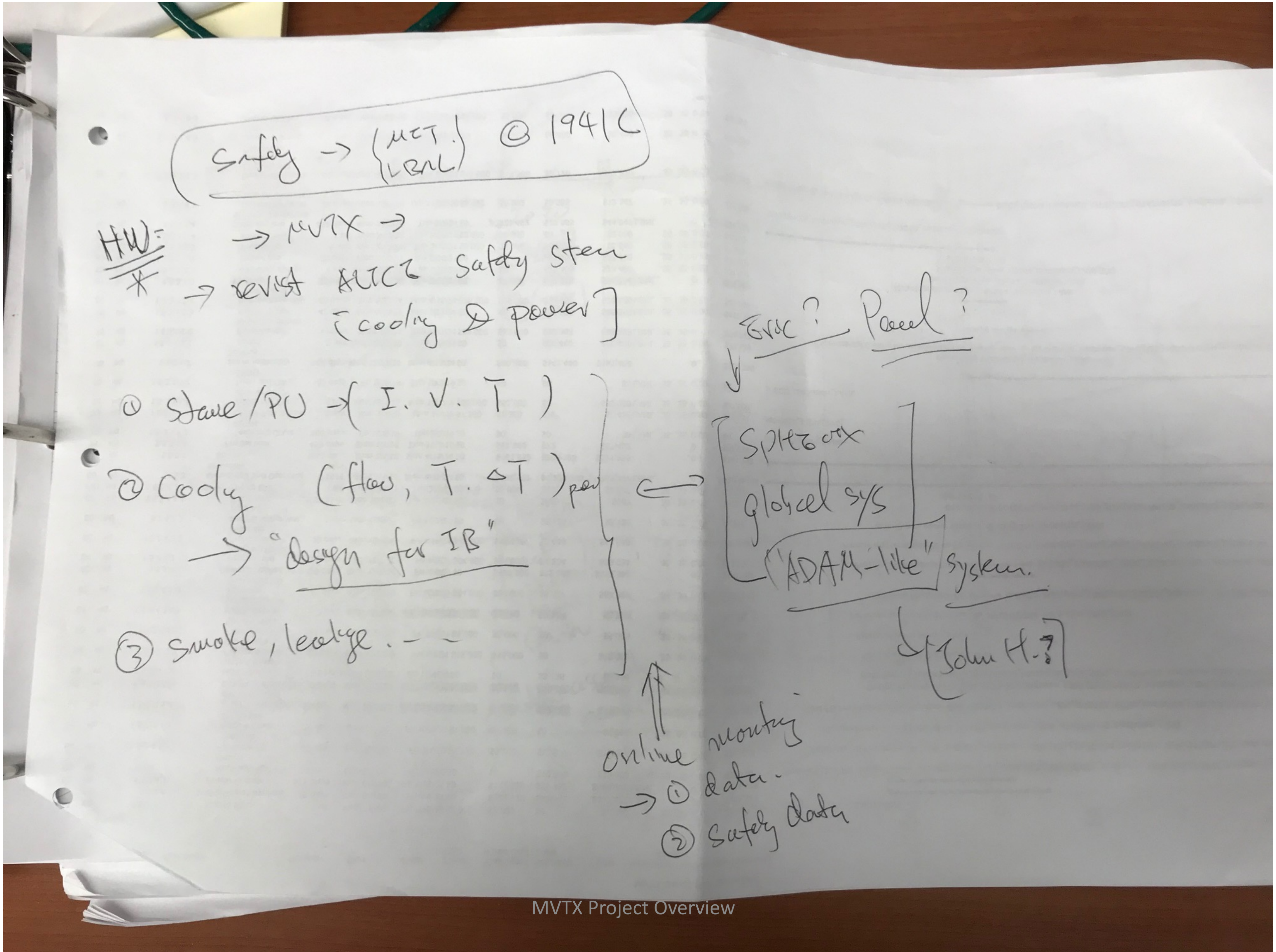


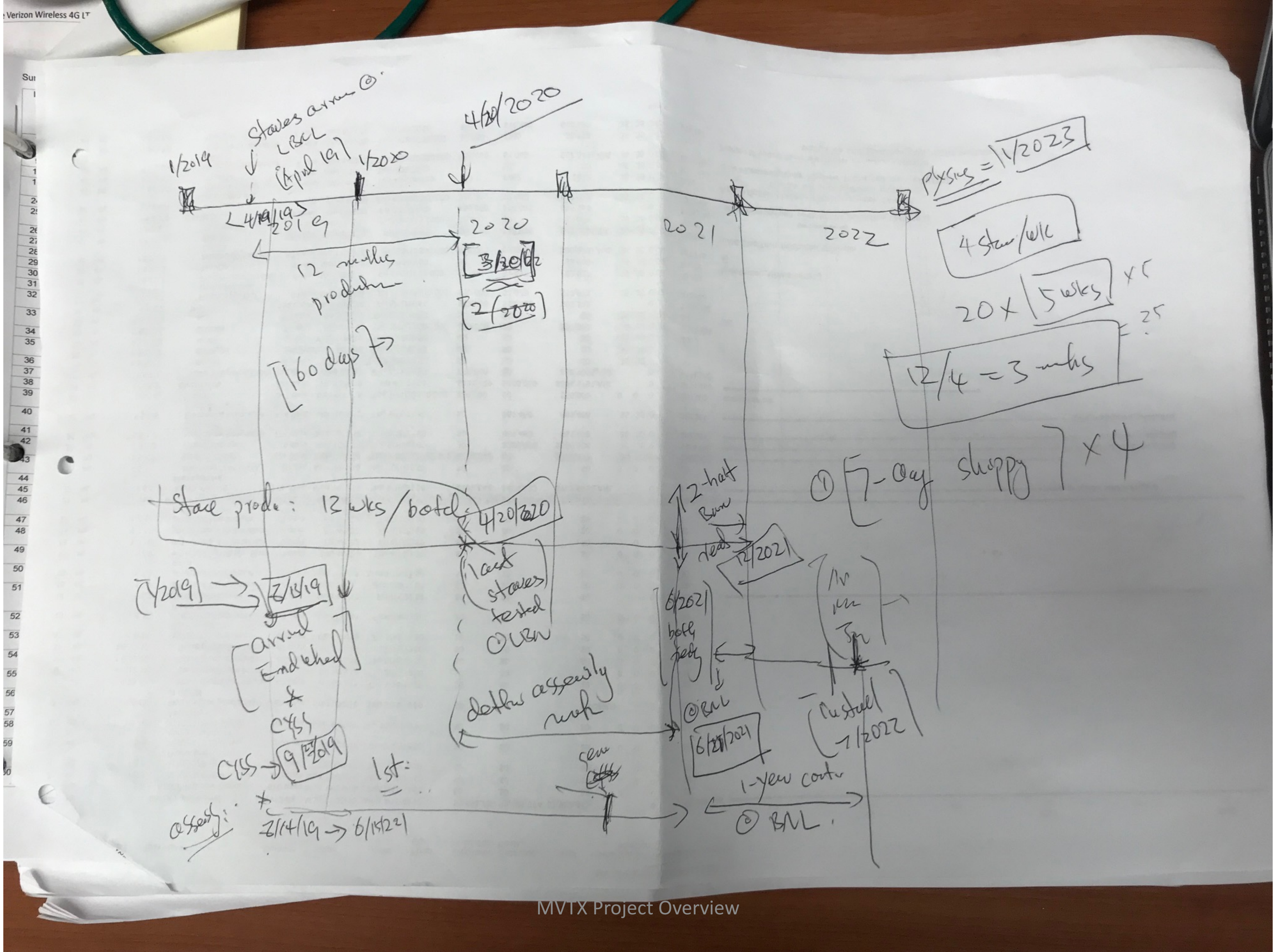
"B meson and b-jet flow"







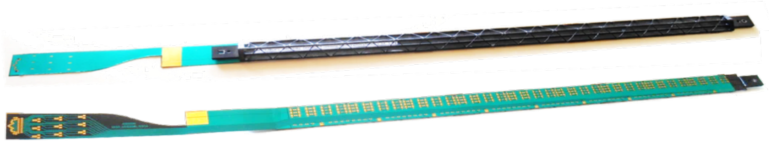

Safety -> {MIT / LBNL} @ 1941C
HW: *
-> MVTX ->
-> revisit ALICE Safety stem
[cooling & power]
① Stave/PU -> (I. V. T)
② Cooling (flow, T. ΔT) pow
-> "design for IB"
③ smoke, leakage . . .
Eric ? Reed ?
[Sphenix
global sys
"ADAM-like" system.
-> [John H.?]
online monitoring
-> ① data.
② safety data


1/2019
Staves arrive @ LBNL (April 19)
1/2020
4/20/2020
physics = 1/2023
2019
2020
2021
2022
12 months production
3/20/20
2/2020
160 days
4 stave/wk
20 x 5 wks x5
= 25
12/4 = 3 mths
7-day shopping x4
Stave prod.: 13 wks/batch
4/20/2020
1st stave tested @ LBNL
2-half barrel
12/2021
6/2021
1/2019
2/13/19
Arrival Endwheel & CYSS
CYSS 9/2019
detector assembly work
@ BNL
6/2021
install 7/2022
1st:
assembly: 2/14/19 → 6/15/21
1-year constr. @ BNL

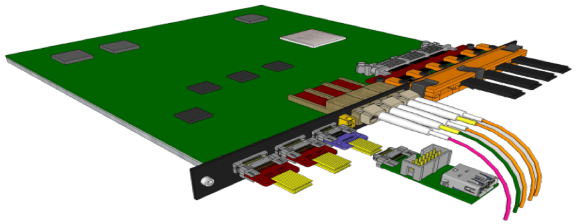
MVTX Sensors and Electronics Production

Major hardware:

- 48 ALICE ALPIDE Staves + Interface Cables
- 48 Front End Electronics (ALICE RUv2)
- 6 Back End Electronics (ATLAS FELIX v2)
- 6 EBDC Linux servers
- 24 Power Boards + CAEN Supplies + Cables
- 48 Stave to RU cables
- 144 data fiber optic cables (3 fibers x 48 FEE)



ALICE ITS/IB stave



ALICE ITS RU

Stave production: total 84, 75% spares

- Two inner layers: 12+16=28
- 10% spares: 8 staves

RU production: 60 in total, 25% spares

sPHENIX vs ALICE

	ALICE (Run3)	sPHENIX (Max)	Ratio of data rates sPHENX/ALICE
Pb+Pb / Au+Au	50kHz	200 kHz	0.3
p+p	200kHz	13 MHz	(1.6)
Trigger/Readout	50 kHz/(C.R.)	15 kHz	-

- MB Event track multiplicity dN/dη
  - sPHENIX = 1/3 ALICE (pp)
  - sPHENIX = 1/5 ALICE (AA)

sPHENIX triggered data rate fits well within ALICE readout hardware specs

Projected Radiation Level after 5-year Runs

http://www.rhichome.bnl.gov/RHIC/Runs/RhicProjections.pdf

sPH-TRG-2018-001

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}

Projected sPHENIX integrated luminosities after 5-year operation

- AuAu: Lum. = 214 nb^{-1}
- pp+pAu: Lum. = 1340 pb^{-1}

PHENIX study
arXiv: 0710.2676 [nucl-ex]

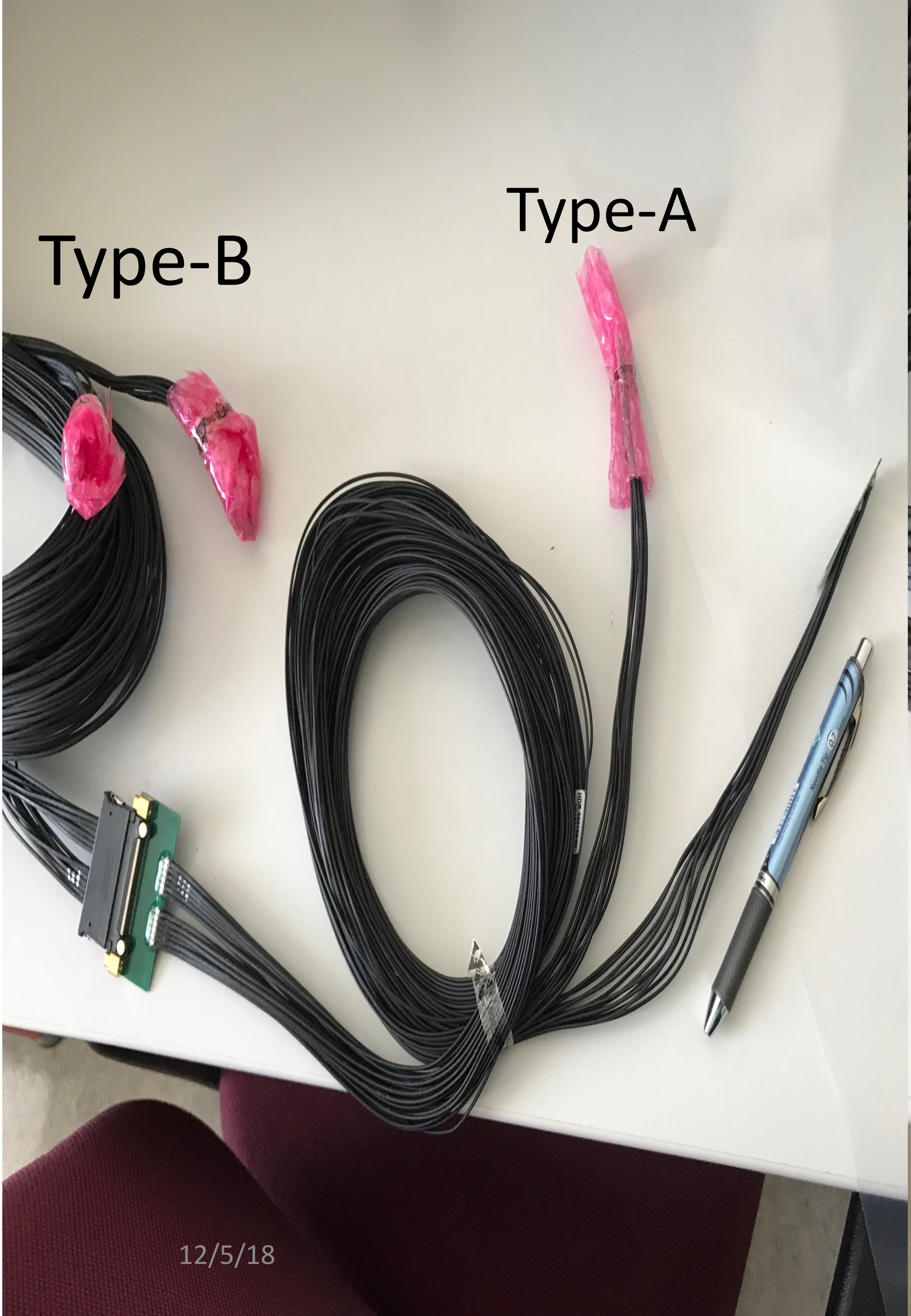
Projected sPHENIX MVTX L0 fluence: TID = 1060krad

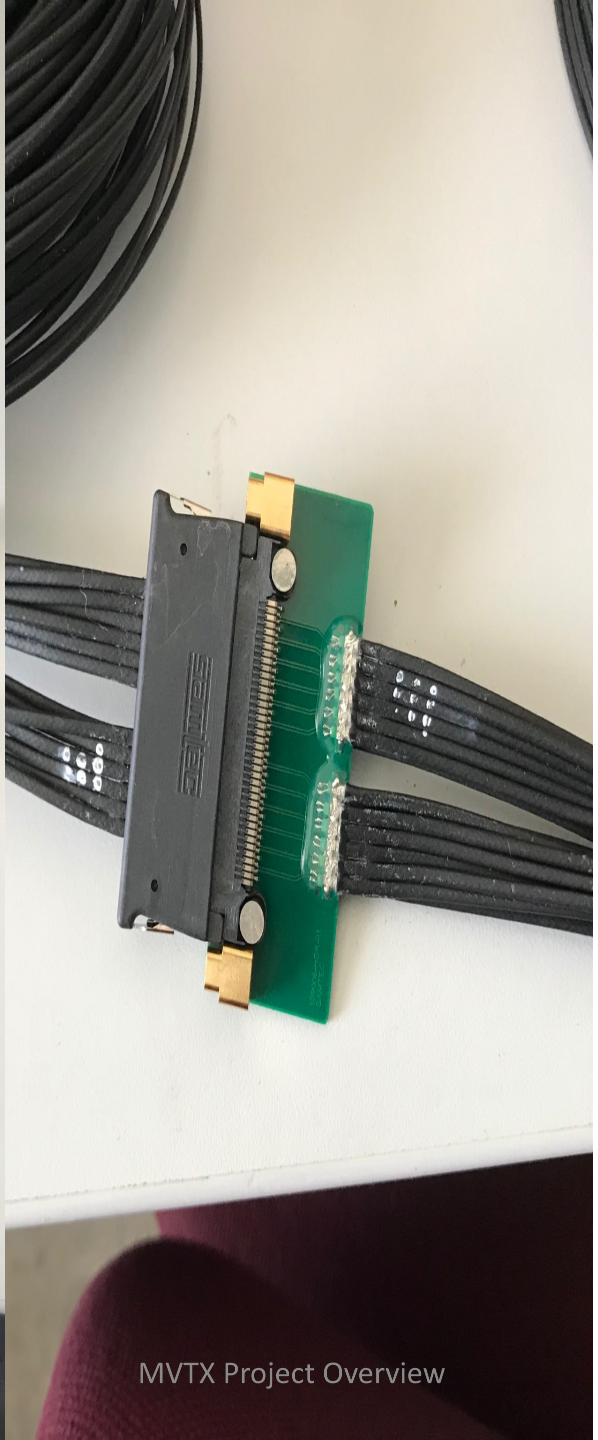
NIEL = $6x10^{12}$ N_{eq}/cm^2

Outer layers:

L1 = 0.6 x L0; L2 = 0.4 x L0

Sensors tested to full MVTX NIEL and ~3x TID @ALICE

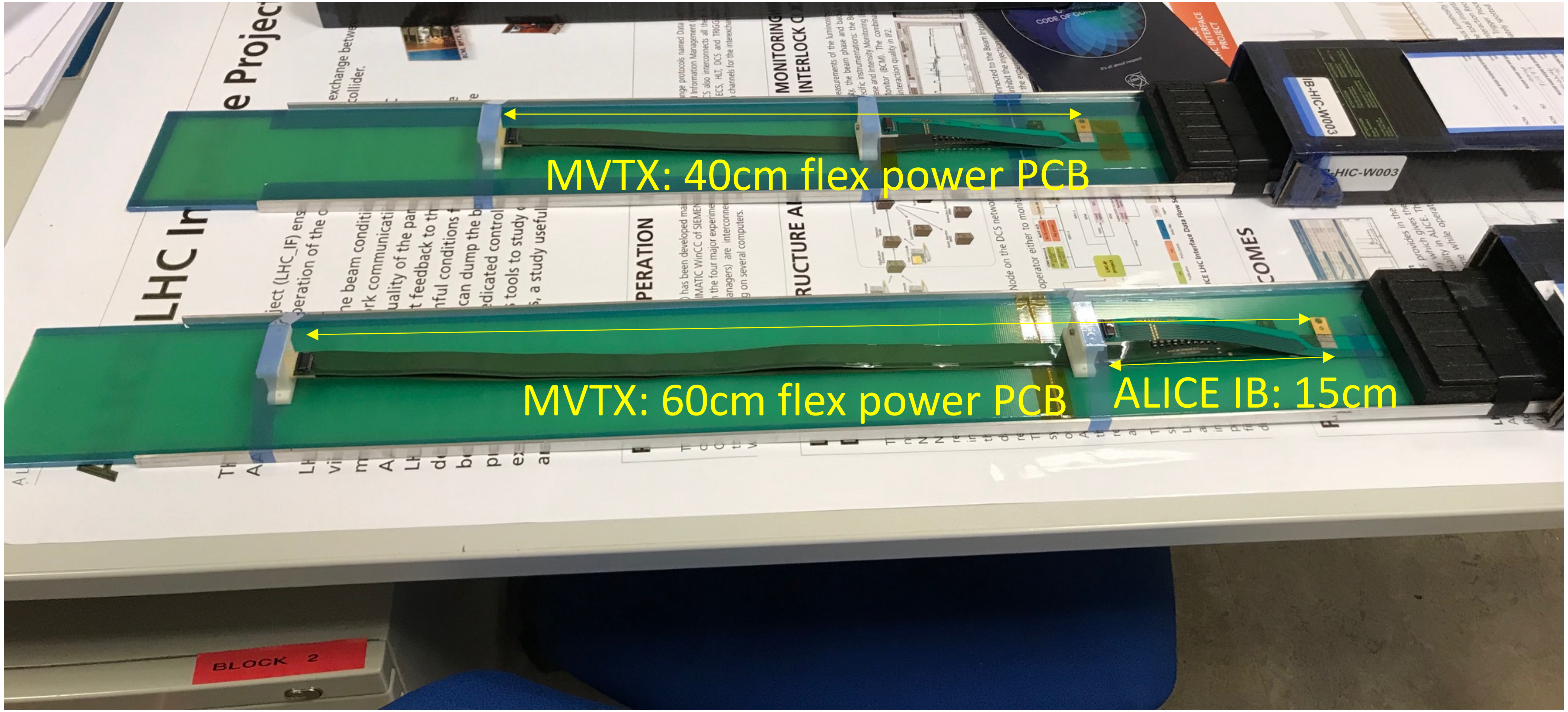

Type-B
Type-A




Type-A

Two HICs Produced and Tested at CERN w/ Extended Power Cables

NO noticeable difference in sensor performance, as expected



HICs Test Results from CERN

- Threshold and noise (from charge injection turn-on curve) are indistinguishable
- Other tests also see no change: supply currents, high-speed data transmission

After: same ALICE HICs, replaced power FPCs

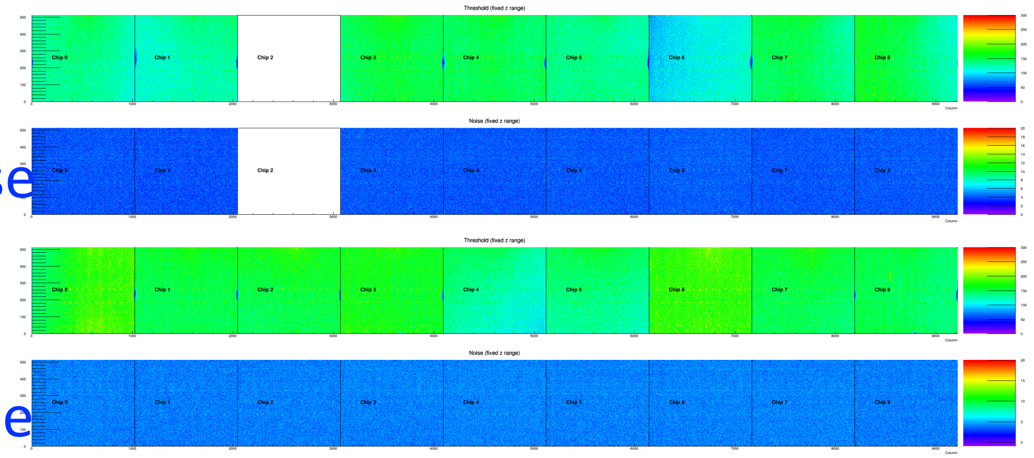
- 15 cm: **Before: 2 ALICE IB HICs**
- top 40 cm, bottom 60 cm:

Thr.

Noise

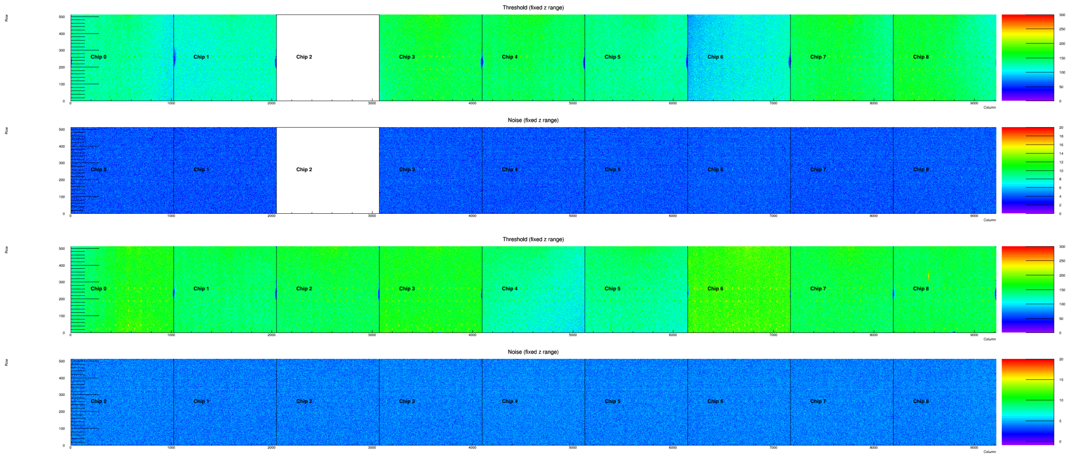
Thr.

Noise



HIC1

HIC2



Noise level: ~4 e's; Threshold: ~180e's; MIP: ~1000 e's

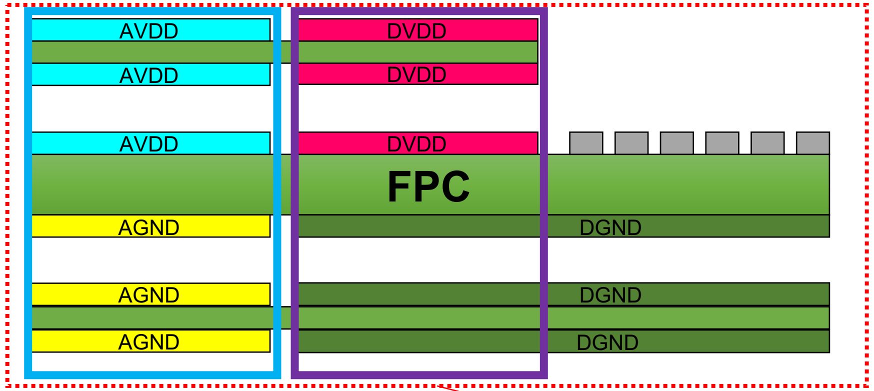
Chip-0

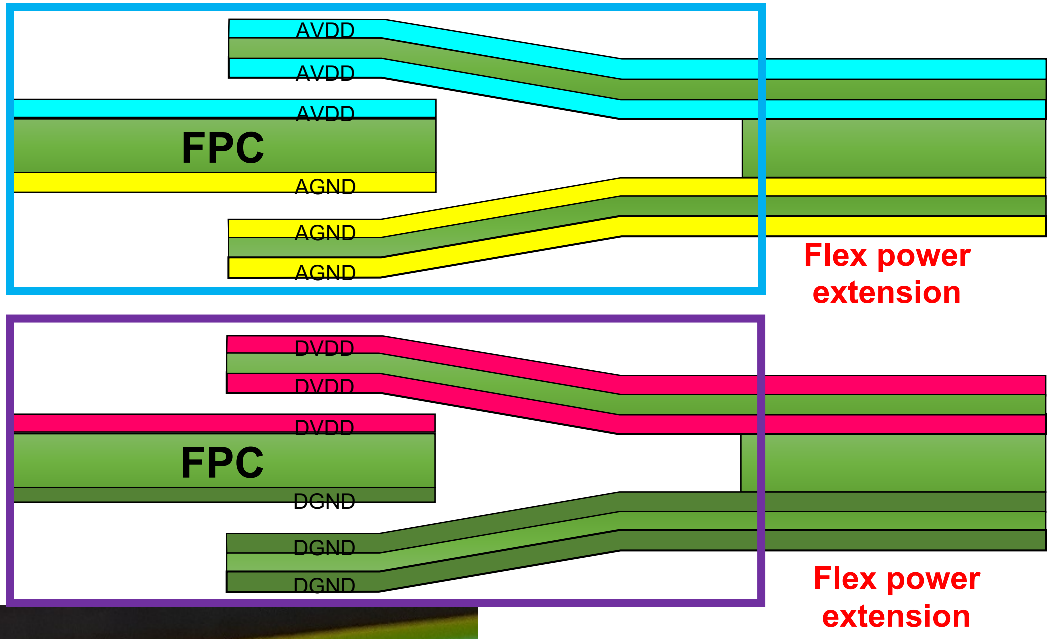
Chip-8

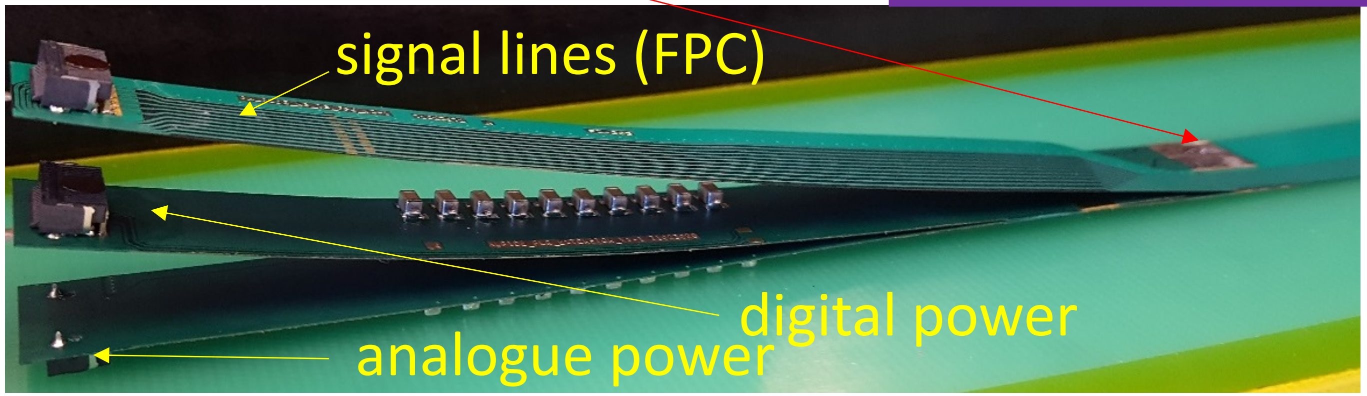
FPC Extension for Connection to Electrical Services

The connection to the service cables is achieved by a double FPC extension which is soldered to the HIC

x-section at interconnection between FPC and extensions





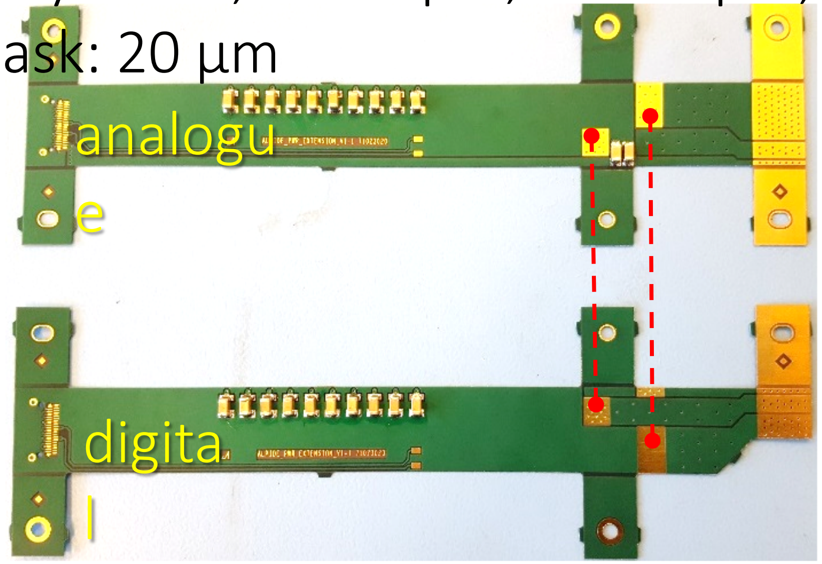


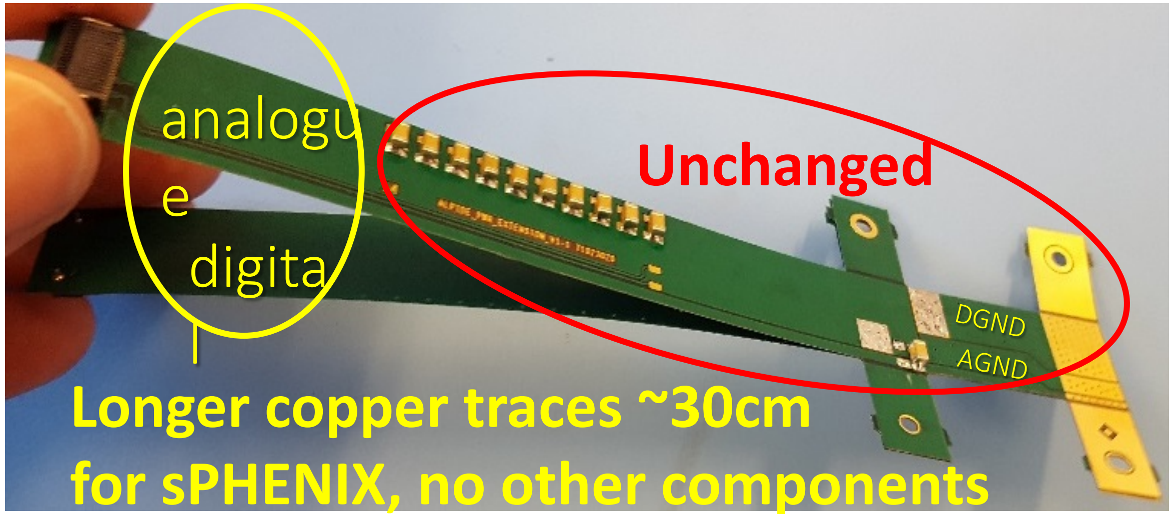
Modified for sPHENIX: 15cm -> 40cm

FPC Extension for Connection to Electrical Services

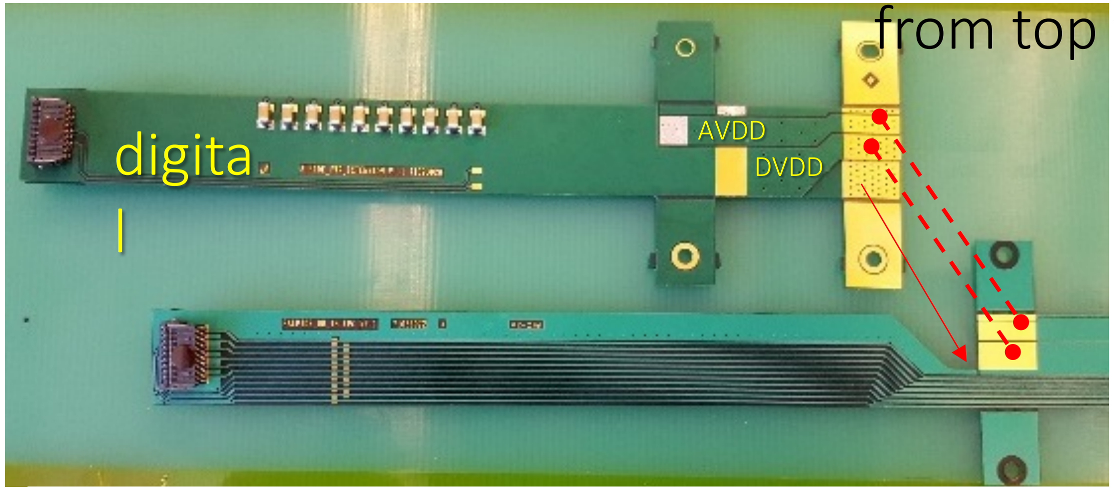
From Antonello Di Mauro
ALICE ITS Upgrade

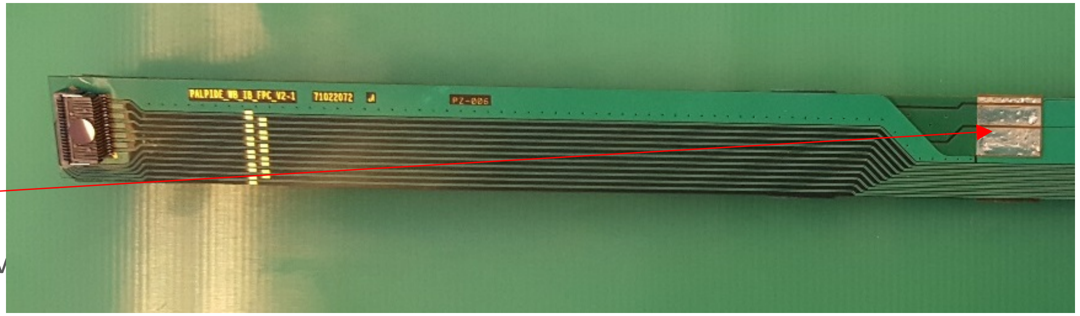
2-layer flex, PI: 50 µm, Cu: 35 µm, solder mask: 20 µm





The two flexes are connected together, AVDD is transferred from top to bottom

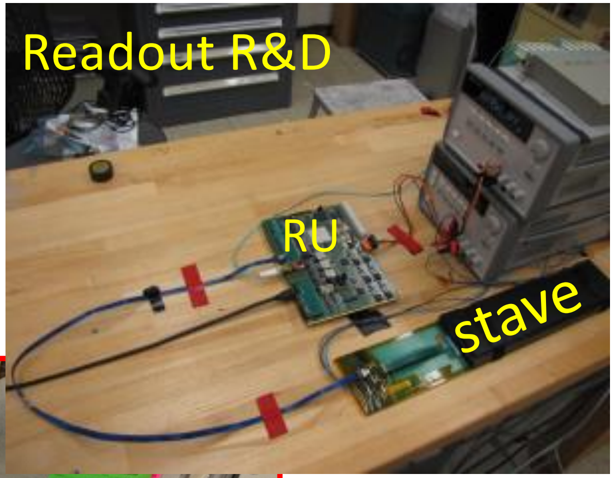


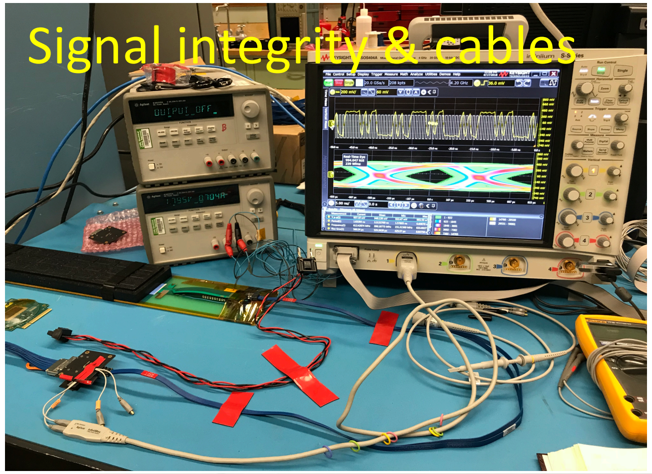


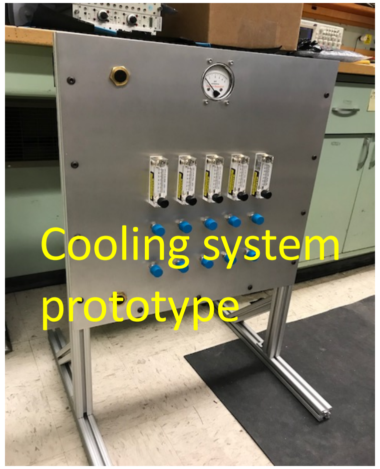
The PWR extension is connected to the FPC by iron soldering and wings are cut.

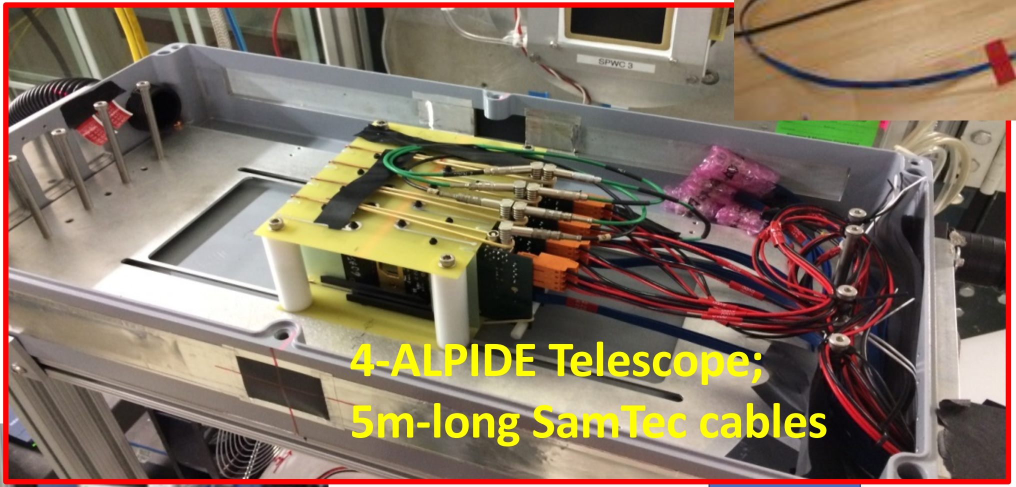
LANL LDRD Activity Highlights

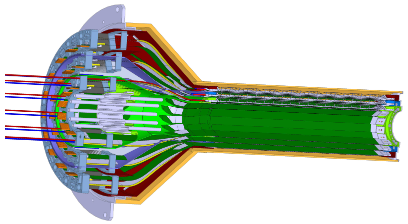
- MAPS evaluation
- Readout integration
- 4-sensor telescope
- Test beam at Fermilab
- Mechanical & cooling

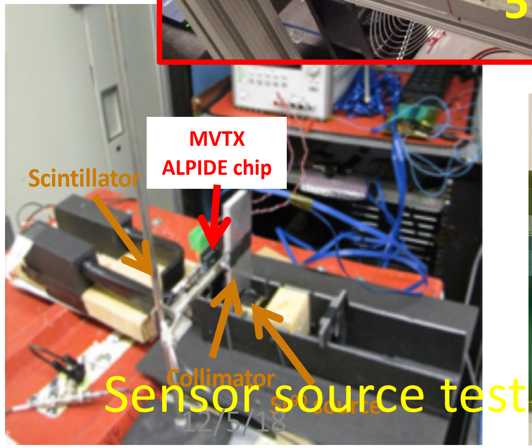


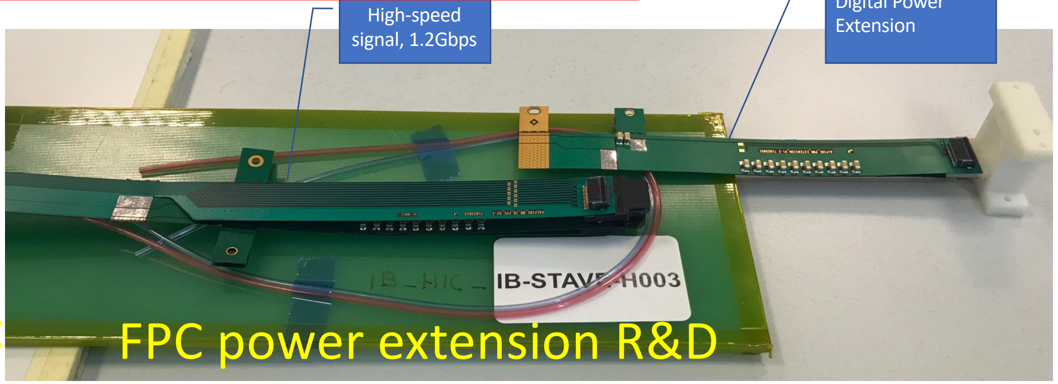










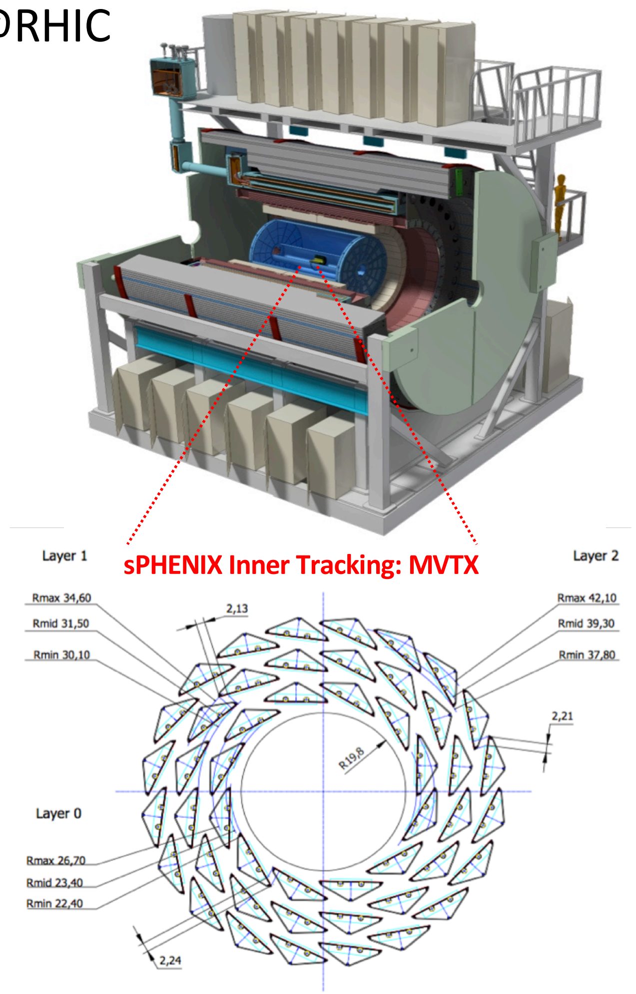


sPHENIX/MVTX IB Stave Assembly Procedure at CERN by ALICE ITS Group

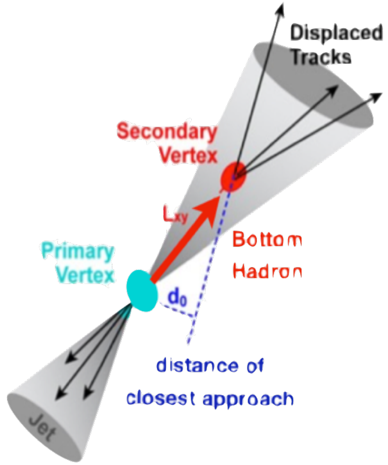
1. Prepare sensors and FPC
2. Glue 9 sensors to FPC
3. Wire bonding 9 sensors to FPC
4. Solder power flex PCB to FPC
5. Glue HIC to coldplate/carbon space frame
6. A stave is ready for QA
7. CMM

MVTX: MAPS-based VerTeX Detector

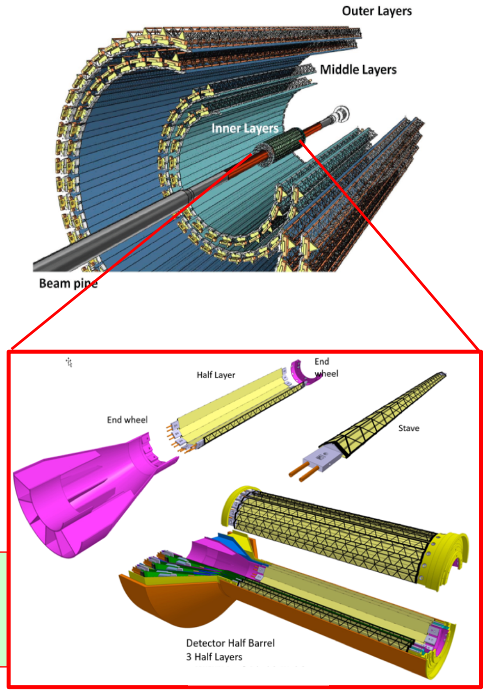
sPHENIX@RHIC
(2023+)



Key integration tasks:
- Readout
- Mechanics



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



“Adopt” ALICE ITS/IB:
- Minimum risk
- Maximum physics

Leveraging on extensive R&D and design work by ALICE

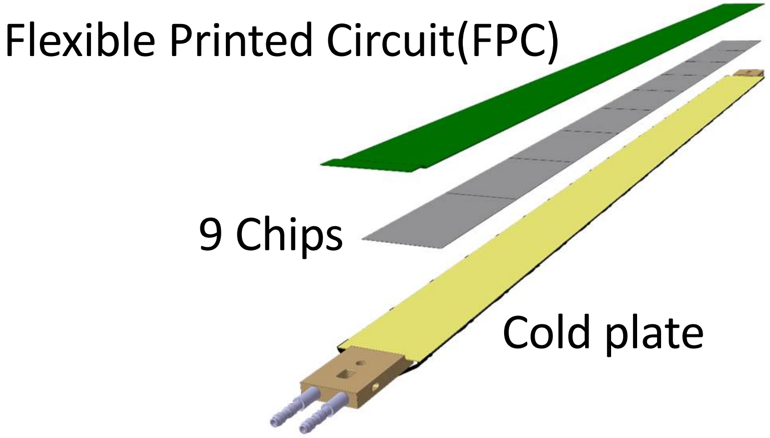
Monolithic Active Pixel Sensors (MAPS)

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

Advantages of ALICE PIxel DEtector (ALPIDE) sensor:

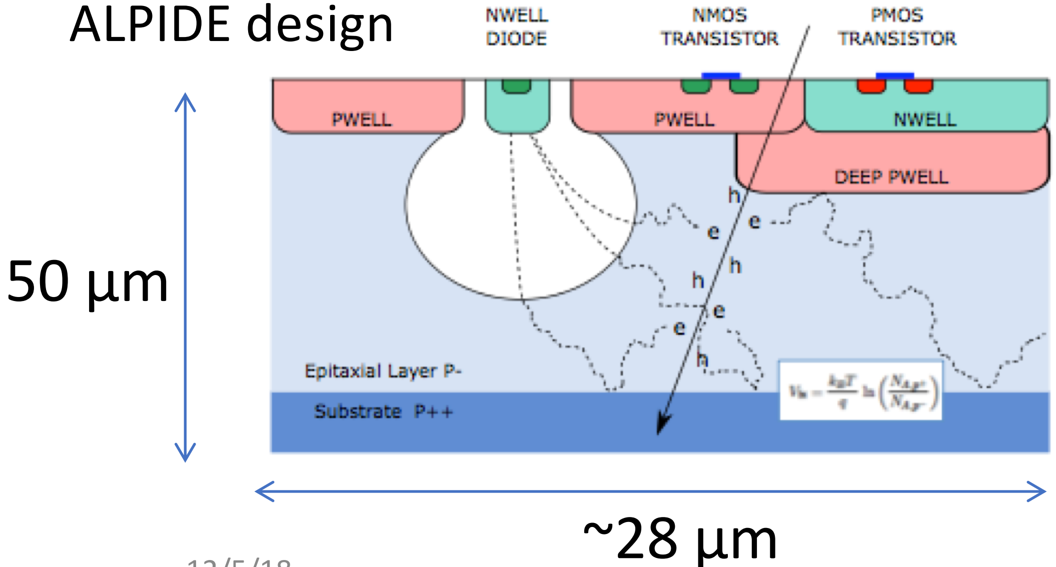
- Very fine pitch (27µm x 29µm), for superb spatial resolution
- High efficiency (>99%) and low noise ($<10^{-6}$), for excellent tracking
- Time resolution, as low as ~5 µs, for less pileup
- Ultra-thin/low mass, 50µm (~0.3% X_0), for less multiple scatterings
- 0.5M channels with on-pixel digitization, for zero-suppression and fast readout
- Low power dissipation, 40mW/cm^2, for minimal service materials

An ideal detector for QGP physics!



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

ALPIDE design

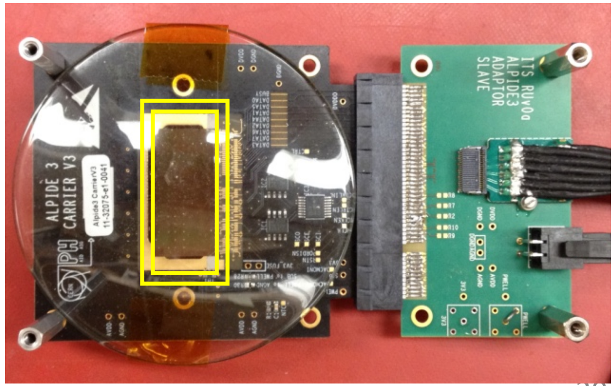


Tower Jazz 0.18 µm CMOS

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

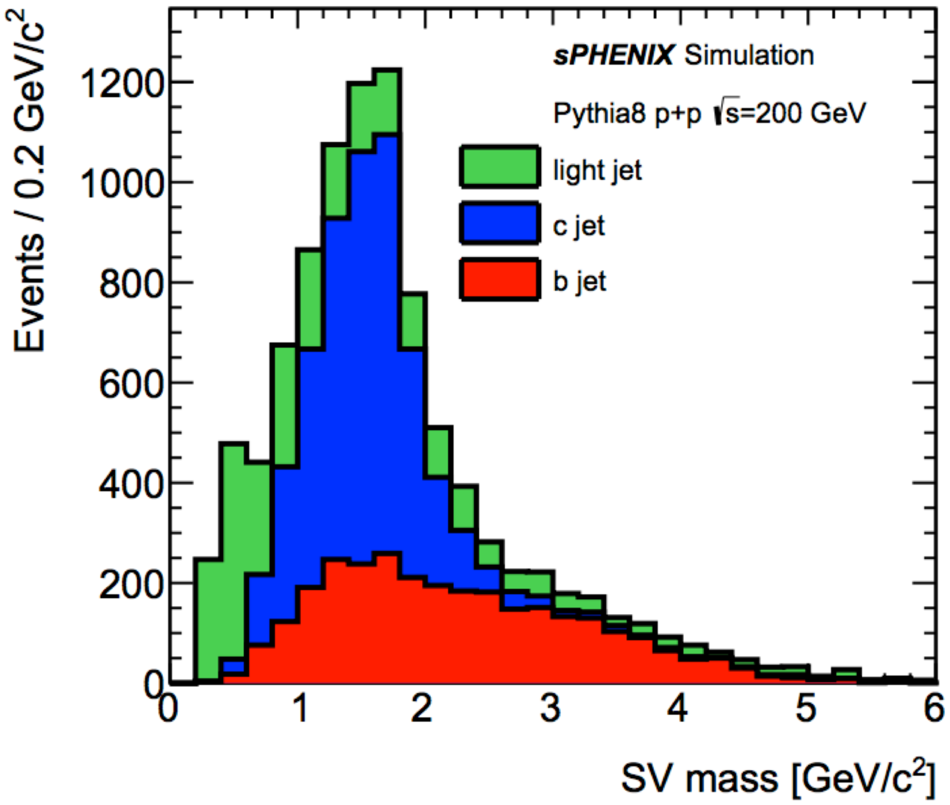
substrate:	$N_A \sim 10^{18}$
epitaxial layer:	$N_A \sim 10^{13}$
deep p-well:	$N_A \sim 10^{16}$

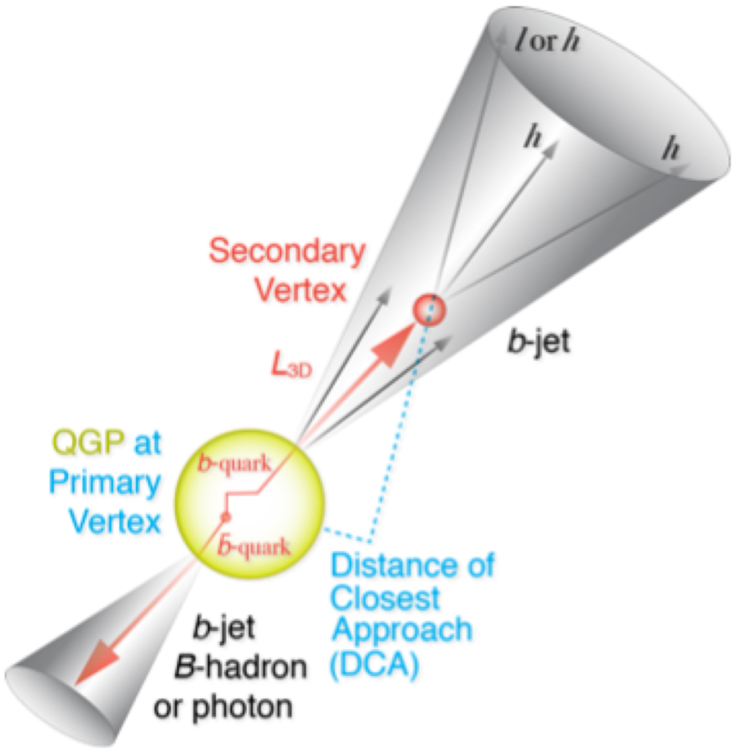
ALPIDE sensor:
1.5cm x 3.0cm, 0.5M channels



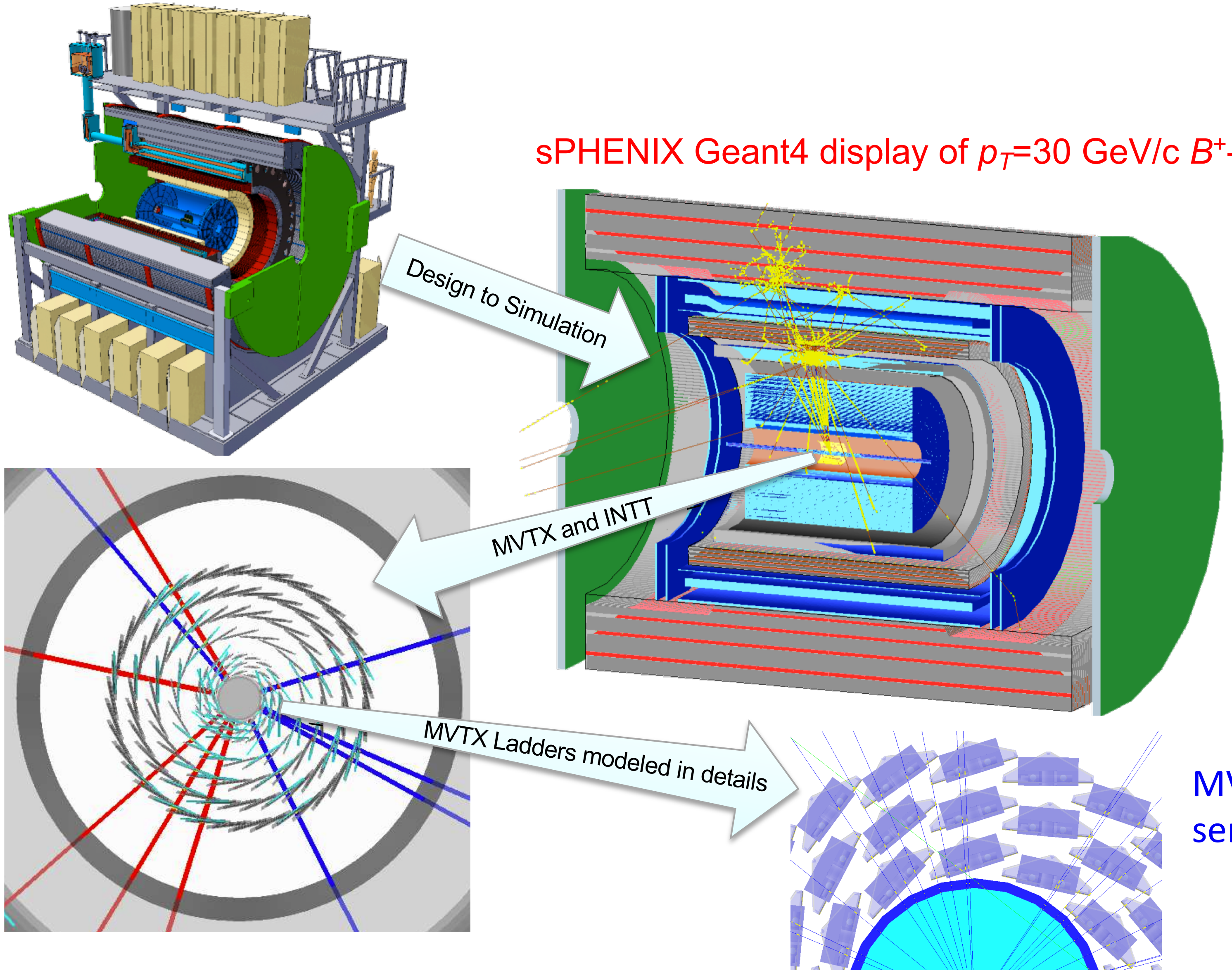
B-Hadron & b-Jet Tagging

- 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!**





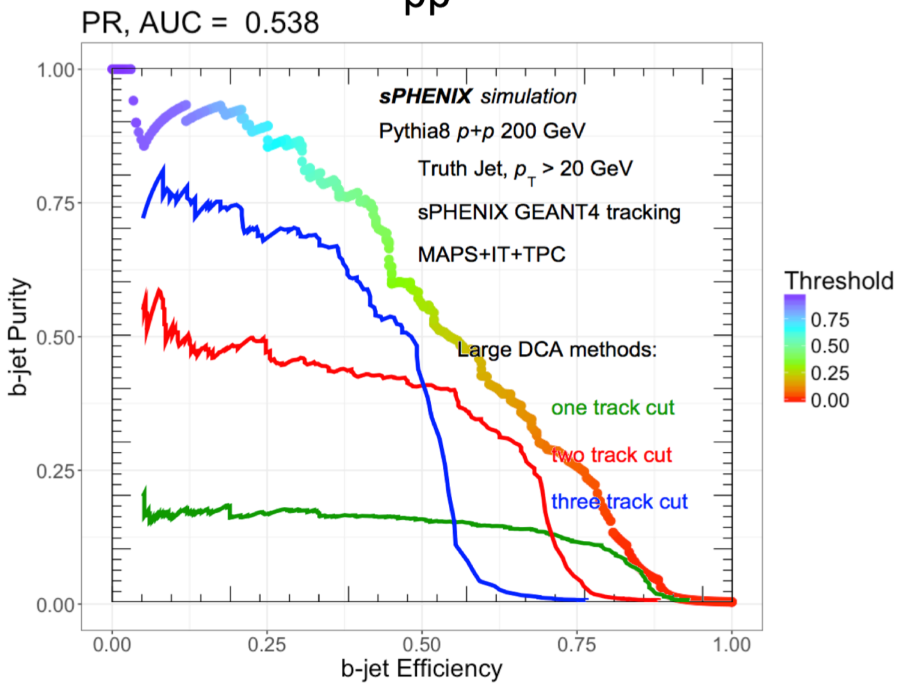
Simulation for *b*-jet and *B*-meson tagging



Expected Performance

Tony's talk

pp



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