MVTX Scope & Overview

Ming Liu, for the MVTX Group
Los Alamos National Laboratory

MVTX Interim Design Review
November 19, 2018

Today's Agenda

13:00 → 13:20 Scope and Overview, 20'
Speaker: Ming Liu (Los Alamos)

13:20 → 13:40 Electronic Components, 20'
Speaker: Sho Uemura (Los Alamos National Laboratory)

13:40 → 14:20 Mechanical Components and Installation, 40'
Speaker: Walter Sondheim (Los Alamos National Laboratory)

Department of Physics

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Memo

Date: November 15, 2018

To: Dave Lynn, Dan Cacace, Don Lynch, Jim Mills, Richie Ruggiero, Mickey Chiu

From: John Haggerty, Glenn Young

Subject: MVTX Review

There will be an Interim Design Review for the MVTX components to be purchased in the near future on Monday, November 19, 2018 in 2-219. The agenda and BlueJeans connection information are here:

https://indico.bnl.gov/event/5351/

The purpose of the review is to determine whether the state of readiness of the design of the MVTX allows the purchase of components from CERN and other purchase expected in the coming months. Since the purchased components are to be installed in the detector, a key question is to assure sPHENIX management that plans for detector installation are sufficiently advanced to reasonably ascertain that the components fit in the allowed envelope and can be installed into the crowded inner bore of the TPC. Before the purchases are made, a Procurement Readiness Review will be held to check the orders for the components.

This review is needed to satisfy the normal cadence of sPHENIX design and procurement reviews, and to satisfy a recommendation of the PMG:

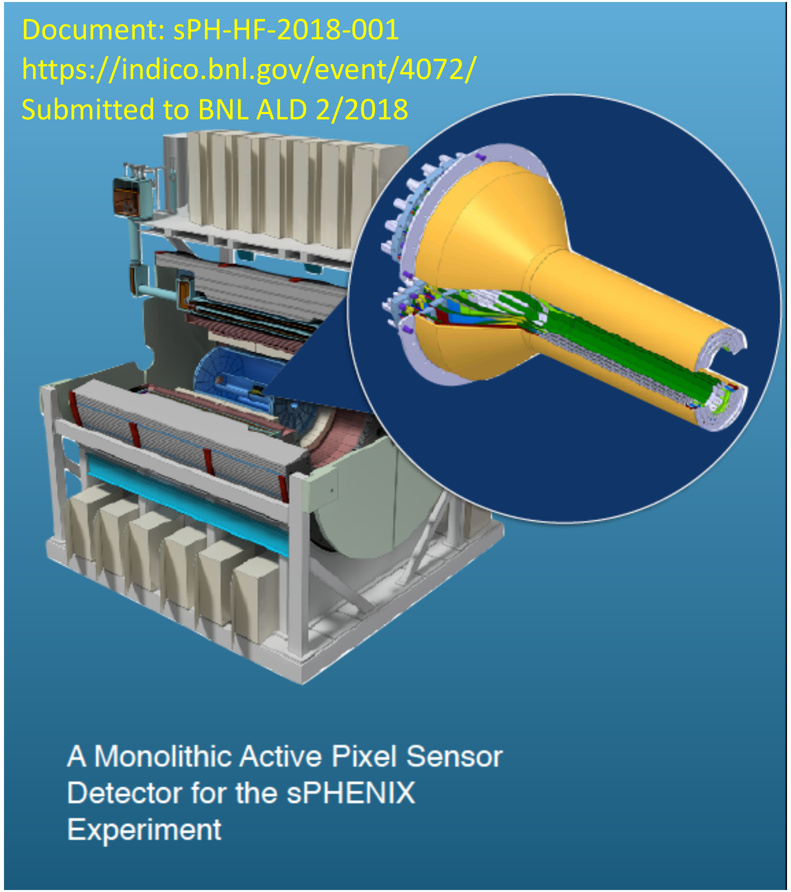
"Conduct a technical review with subject matter experts for the installation of the MVTX into sPHENIX (conduct before November 14, 2018). The details of the installation need to be understood and agreed upon before issuing the procurement for the power cables."

The sPHENIX draft guidelines for an Interim Design Review are:

An IDR is a detail component, subassembly, fixture, tool, equipment or services level review held when the item design concept has matured to the extent that the item is ready to be detailed for procurement. This can be at the prototype, pre-production, or final production stage. Reviewers will be mostly internal to sPHENIX but may include key independent experts if deemed necessary by sPHENIX project management. Detail drawings, layouts, 3D models, schematics, analyses, assembly procedures and integration analyses support systems are to be provided to the extent necessary to demonstrate that the item is ready to be finalized for procurement. Safety, schedule and cost risk analyses as appropriate for the item being reviewed are also included.

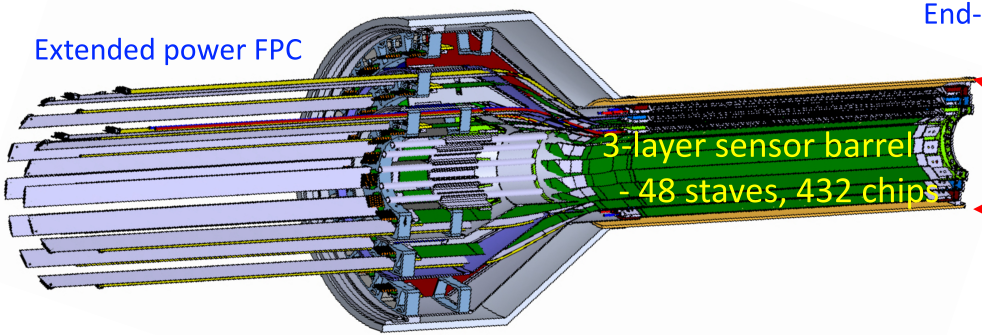
Outline

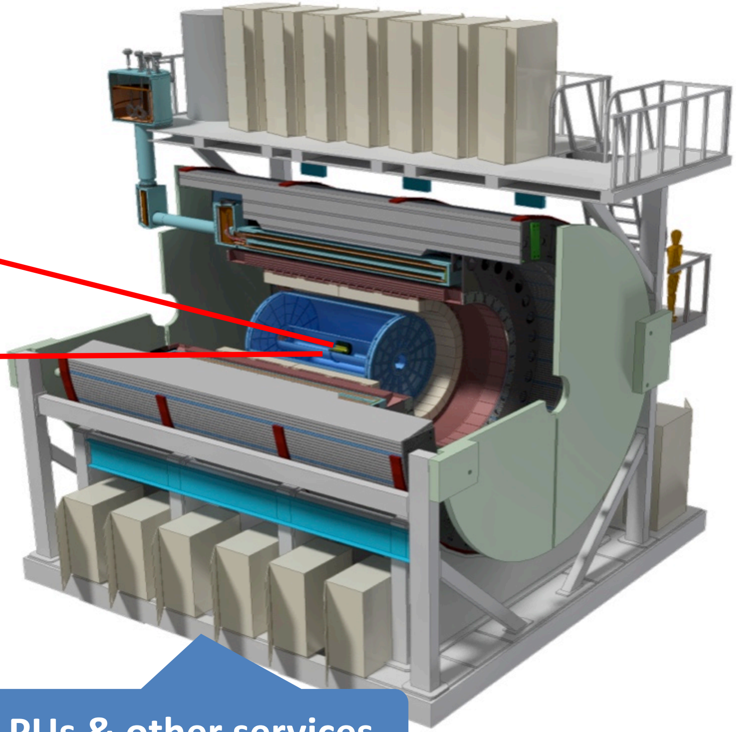
- MVTX technology
- MVTX project scope
- Design and R&D progress
- Near term plan



MVTX Detector

Service cone: signal, power, cooling
and mechanical support





MVTX parameters

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

Scope of the MVTX Project

- MAPS Staves & Electronics
  - Readout Integration R&D by LANL LDRD
  - Frontend: ALICE/ITS, RU
    - Backend: ATLAS FELIX
    - Reprogram RU & FELIX for sPHENIX
  - Production:
    - **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(12)
    - sPHENIX production, 8 ATLAS/FELIX
      - Acceptance test @LANL
    - Final detector assembly in US
      - LBNL and BNL
  - Ancillary systems, "adopt" ALICE system

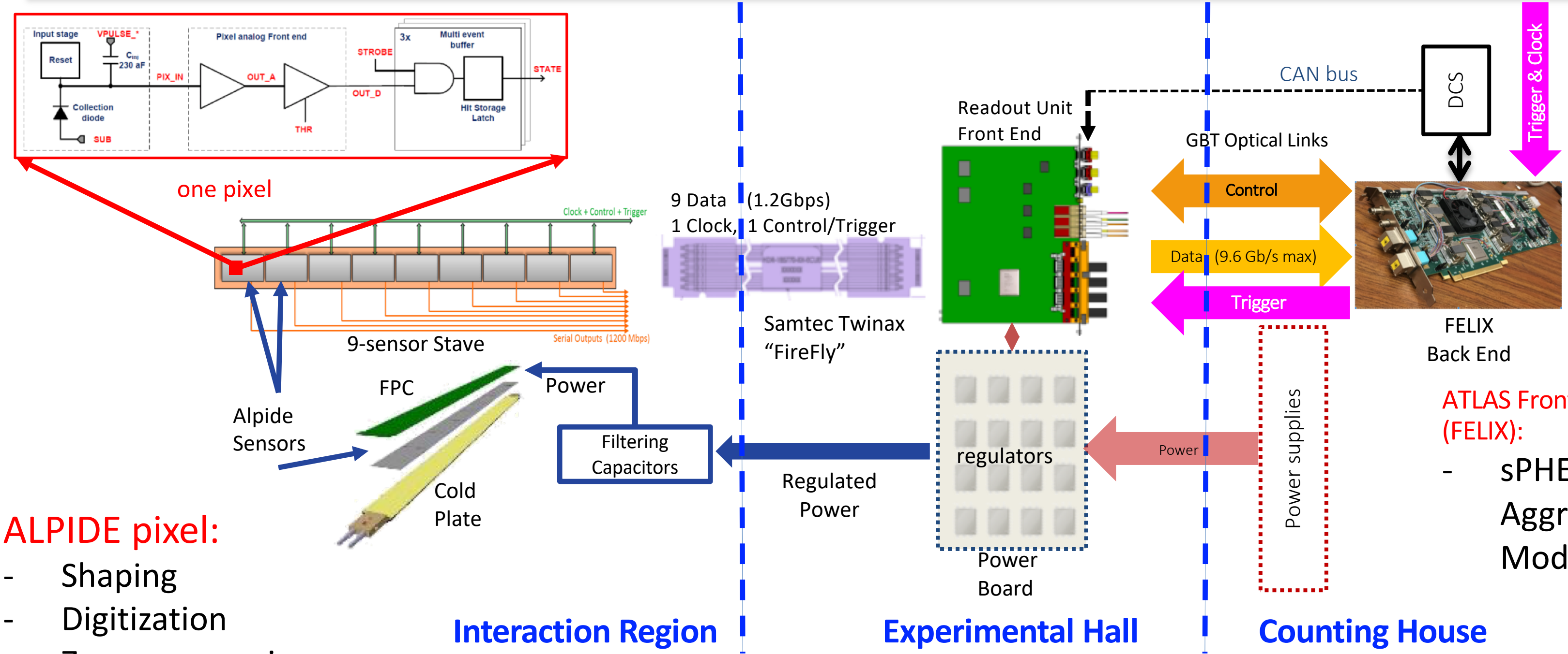
Sho Uemura

- 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 by LANL LDRD
    - Prototype by sPHENIX R&D, MIT/LANL
    - Design integration frames
    - Composite structures, LBNL
    - Installation tooling etc.
  - Adopt ALICE cooling plant design
    - Modifications to fit sPHENIX
    - Much smaller heat load than ALICE ITS

Walt Sondheim

Walt Sondheim

MVTX Readout, Power and Controls



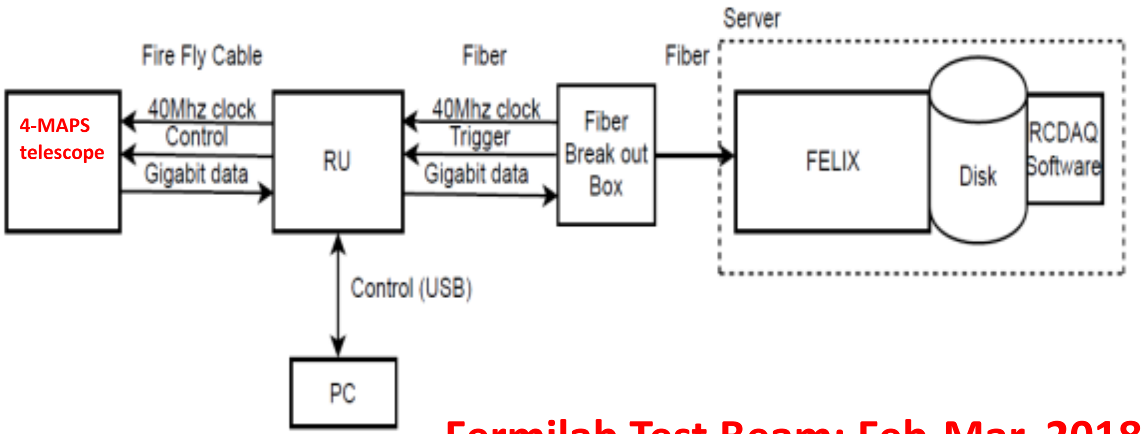
ALPIDE pixel:
- Shaping
- Digitization
- Zero-suppression
- 3x buffer

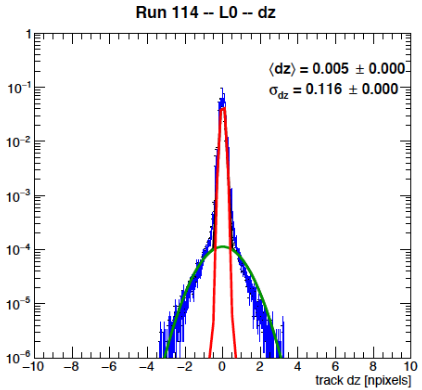
ATLAS Front-End Link eXchange (FELIX):
- sPHENIX Data Aggregation Module(DAM)

MVTX Detector Electronics consists of three parts

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

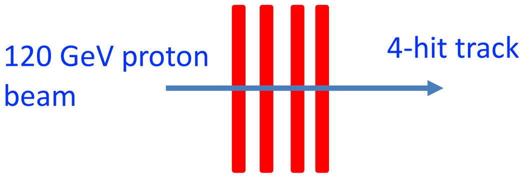
MVTX Full Readout Chain Demonstrated





Tracking spatial resolution achieved: <5 um

Fermilab Test Beam: Feb-Mar, 2018

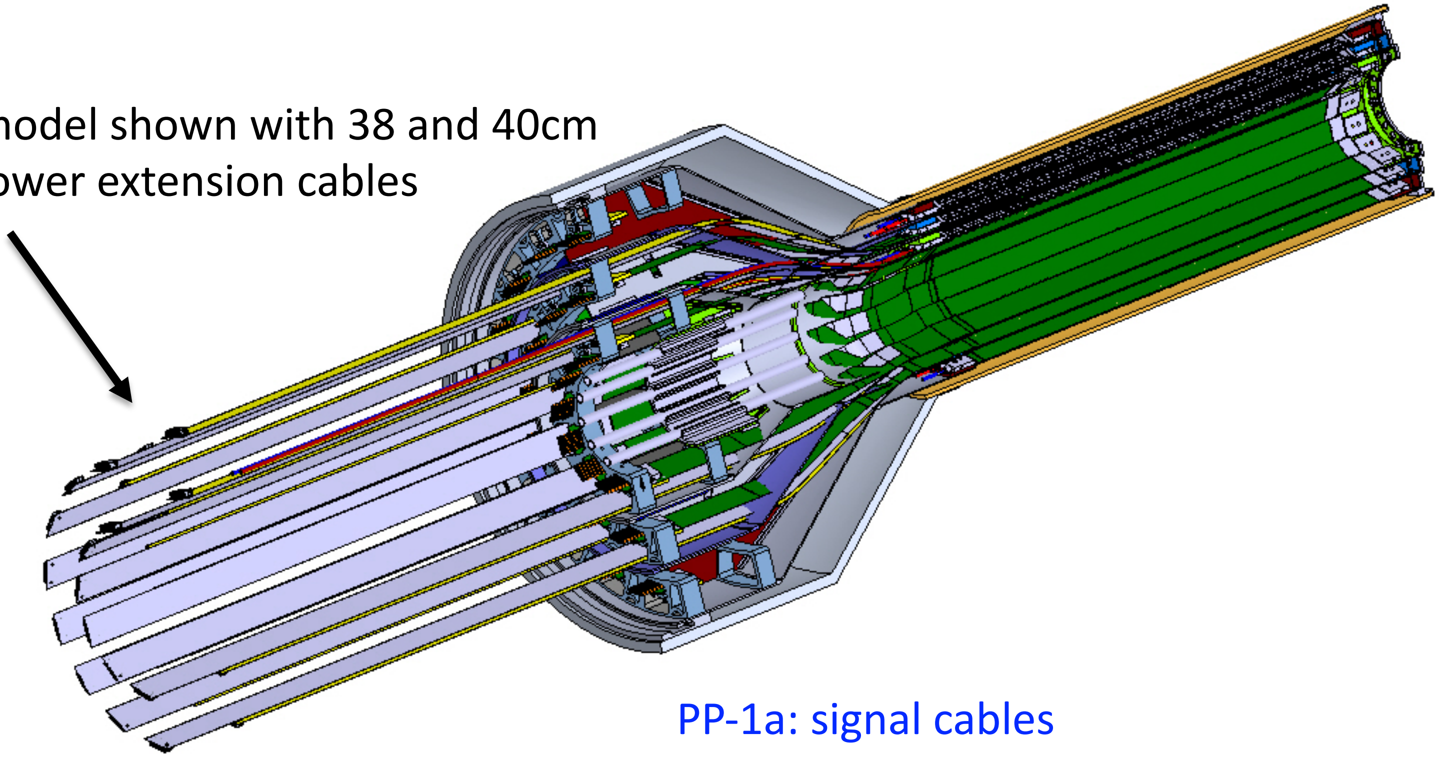


4-MAPS telescope

Updated MVTX Model with Extended Power FPC

Walt's talk

This model shown with 38 and 40cm flat power extension cables



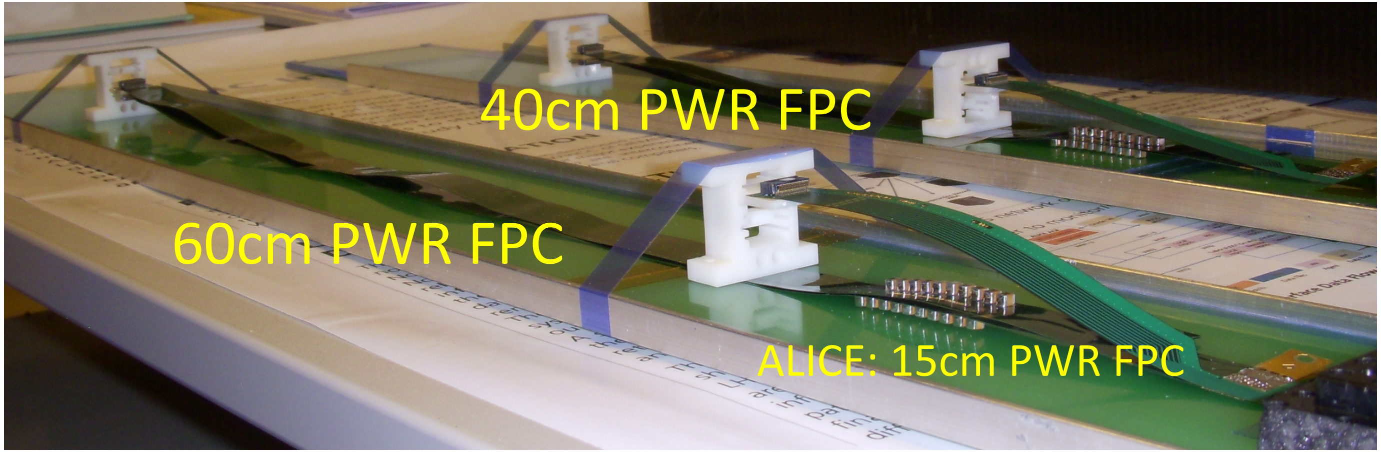
PP-1a: signal cables

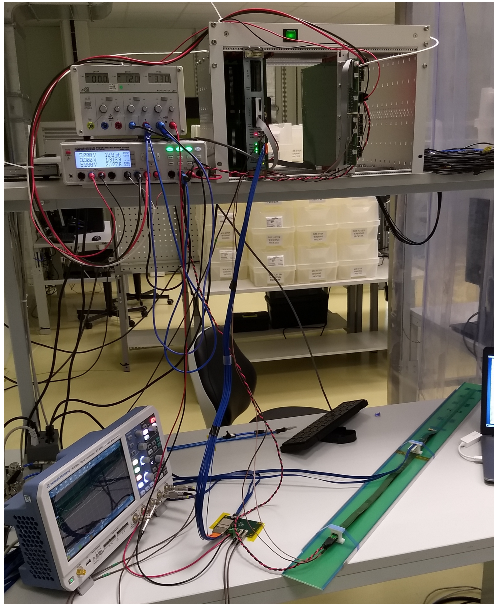
PP-1b: power cables

Confirmed HIC with Extended Power FPC

Sho's talk

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

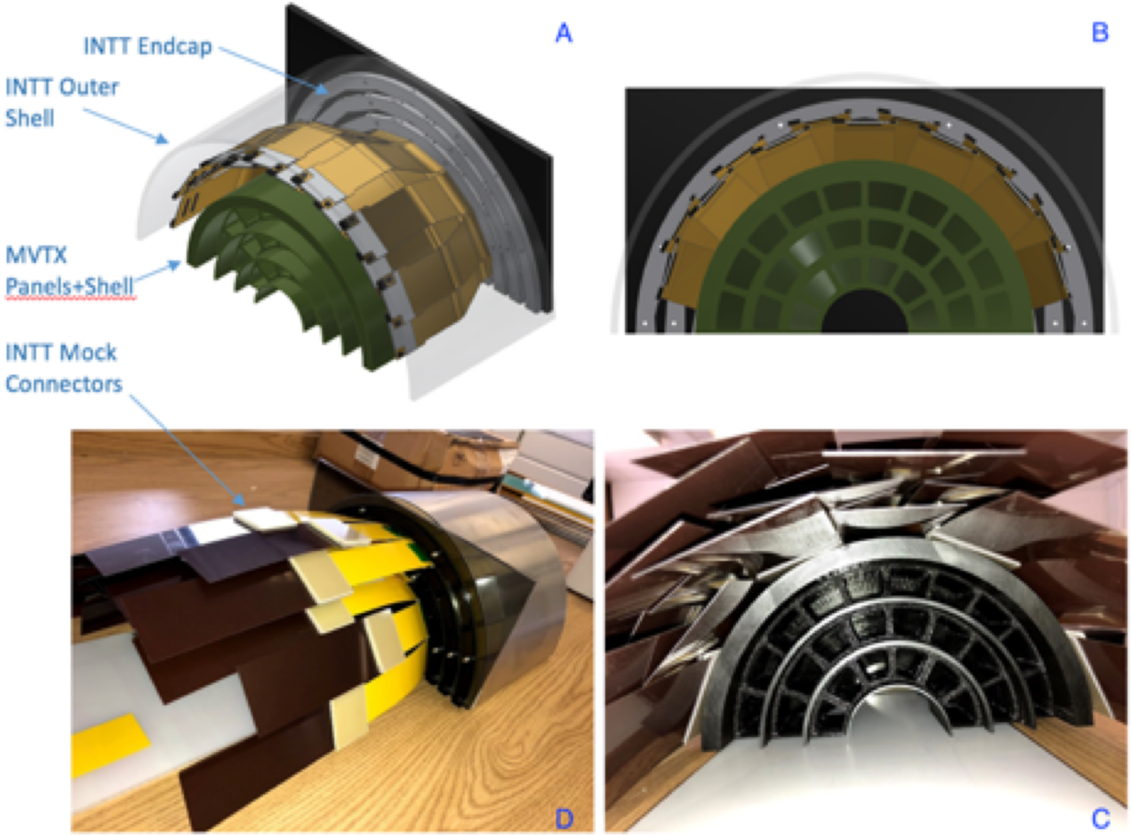




More details presented by Dr. Sho Uemura at last Friday's sPHENIX general meeting 9/23/2018

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

MVTX + 4-layer INTT 3-D Mockup: OK



MVTX and INTT
Space conflict resolved!

ALICE HS SamTec Signal Cables: ~8m!

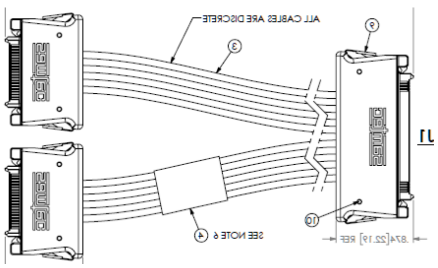
- Two cables per IB stave: 2.65m + 5.30m

Sho's talk

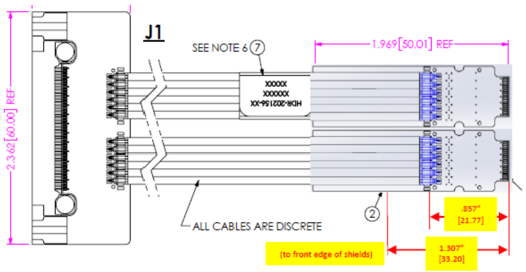
HDR-203194 (Type B)

HDR-206142 (Type A)

Two RUs



PP-2



PP-1

Two Staves

L: 5300 mm

(for sPHENIX, this one could be longer, optimization in progress)

The total length of readout cable < 8m, from stave to RU

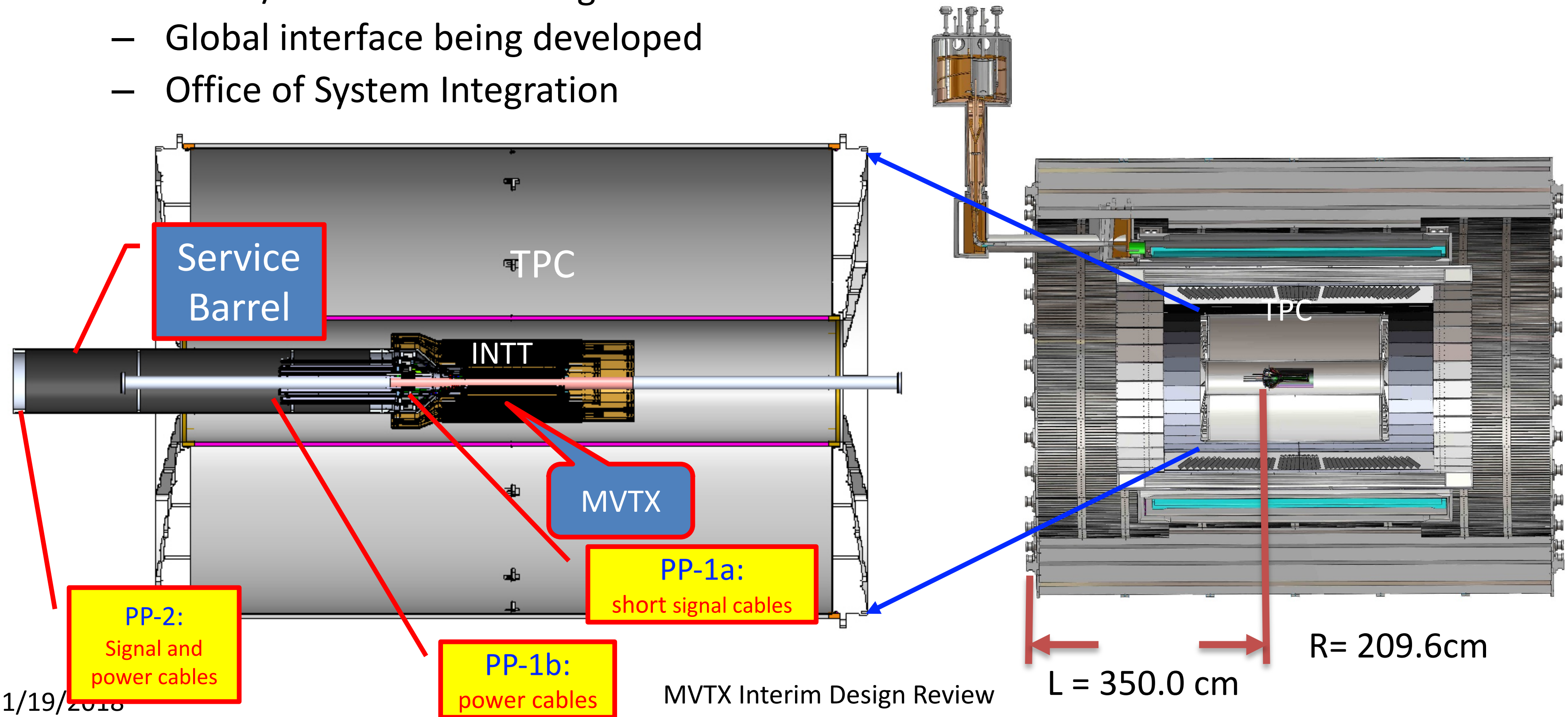
L: 2650 mm

(for sPHENIX, this one could be shorter, ~1m, optimization in progress)

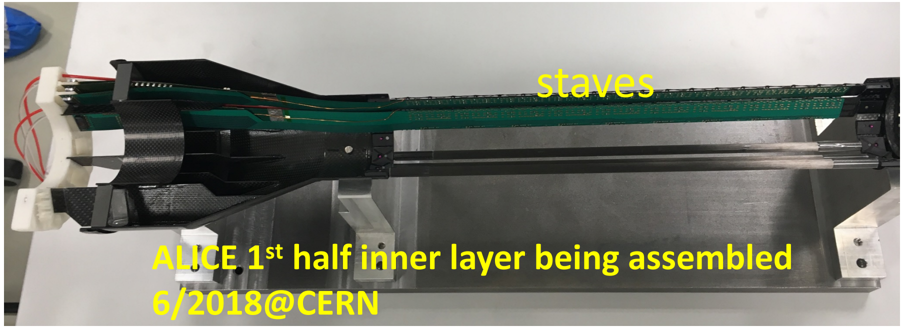
Global Mechanical Integration

Walt & Sho

- MVTX, INTT and TPC/HCal
  - MVTX/INTT detector designs modified
  - Global interface being developed
  - Office of System Integration

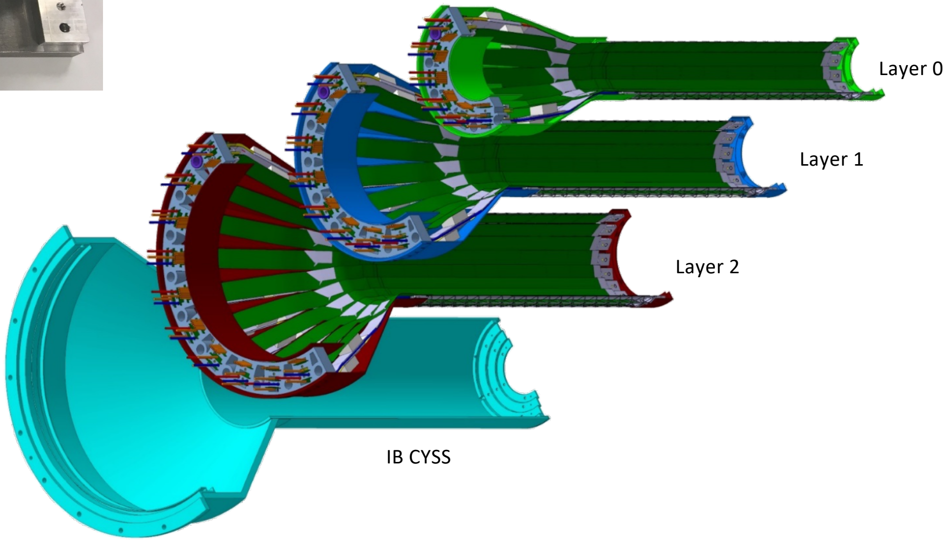


Detector Assembly Plan at LBNL



Precision positioning and installation of staves on end-wheels

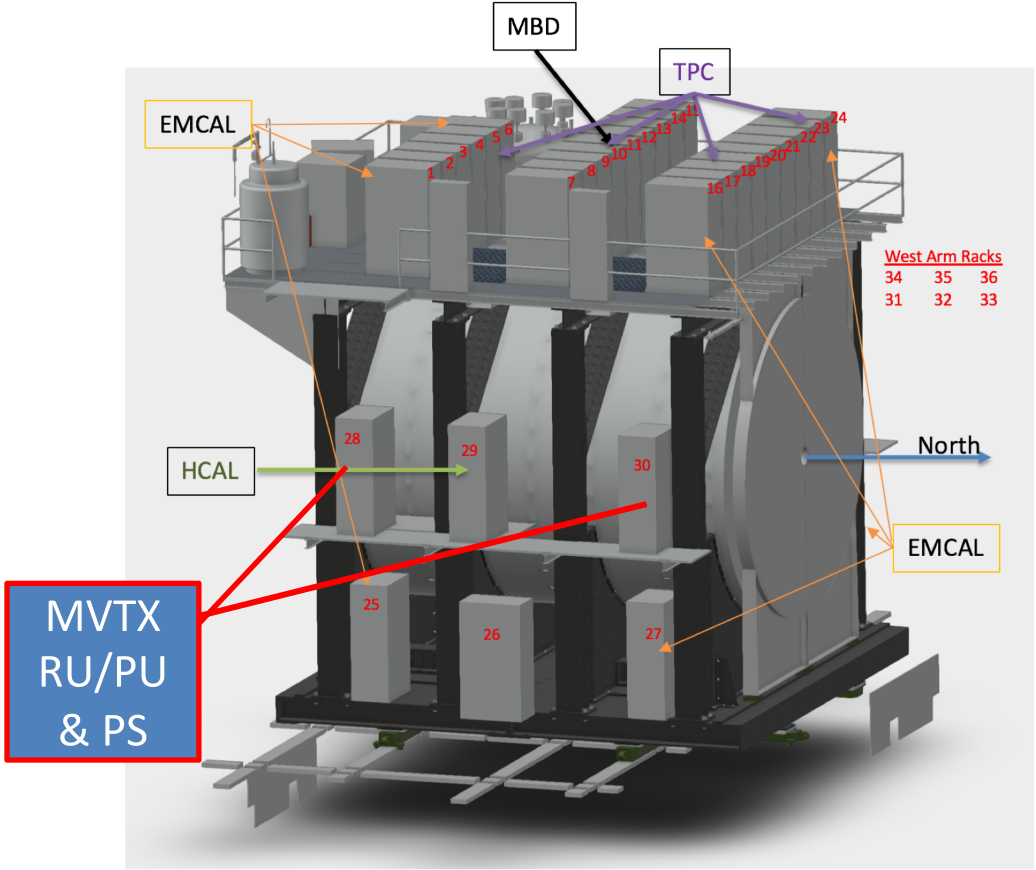
- Follow ALICE IB assembly procedures to build half-detectors for MVTX
- QA records in DB, travelers
- Modified jigs for MVTX
- Build two full half-barrel detector with the service structures



Install SamTec & power cables during half-barrel assembly with the service barrel at LBNL(?,TBD)

MVTX Services

- MVTX Service rack located close to MVTX detector
  - RU
  - PU
  - “Minimal cable length”, < 800cm
- 48 RU and 24 PU
- RU and power units located inside the same crate
  - 1PU ->2RU
- CAEN bulk power supply located on the top platform or on the ground



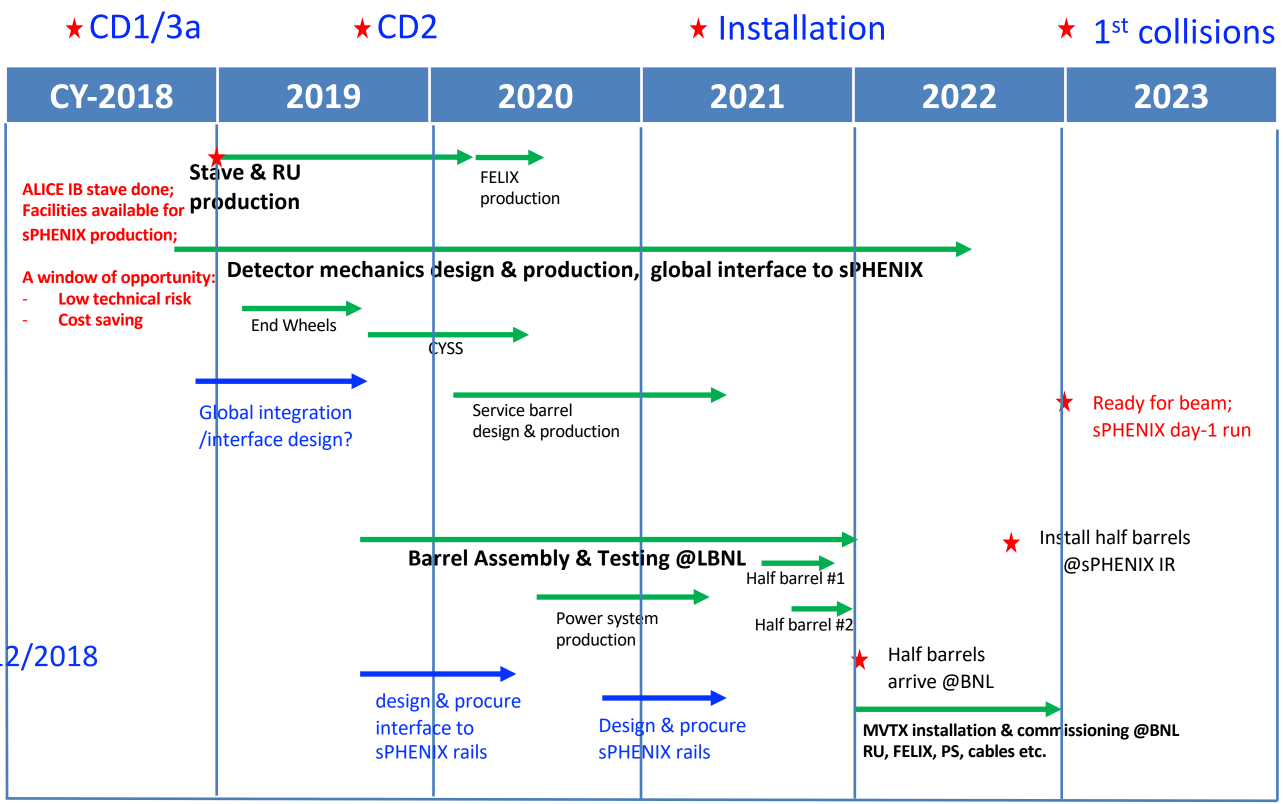
Near Term Task & Schedule

- 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 ~Dec. 2018
    - 3 months (wafer production) + 1 month (dicing & testing)
    - Stave assembly starts @CERN, ~ April 2016, will take 6~12 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 – LANL/MIT/LBNL
  - Carbon structures fabrication @LBNL
  - Non-composite structure fabrication @MIT

Schedules and Milestones

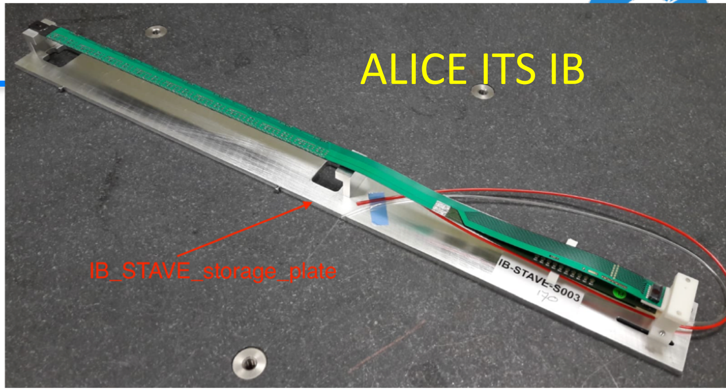


To be finalized @FSU 12/2018
Work in progress:
LANL/MIT/LBNL
Design and fabrication

Recent Progress - I

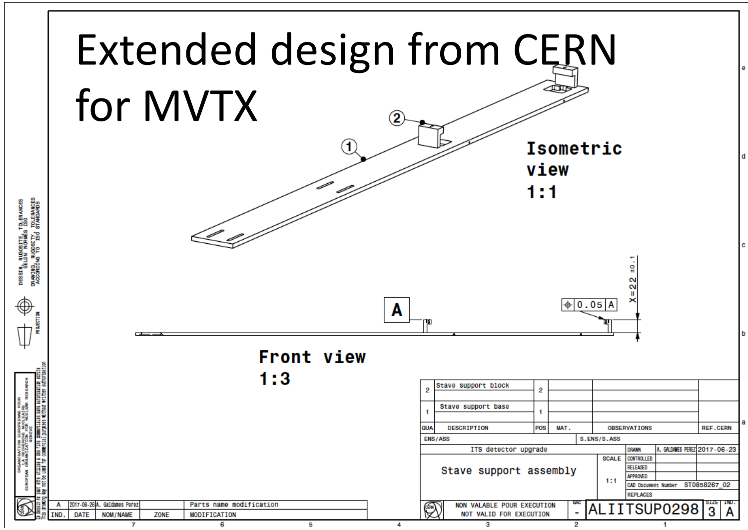
- Completed sensor/HIC/stave evaluations at CERN
  - Built and tested two HICs with 40cm and 60cm long power FPC
    - Confirmed sensor performance same as the ALICE default configuration
  - Sensors irradiated up to 2.7MRad, no problem (updated 9/18/2018).
  - Addressed all recommendations on stave/sensor R&D from recent BNL review
- Technical specs document completed for production
  - Cost are set for staves/RU, UTK has started purchase paperwork
  - RUs, production starts soon as part of ALICE production
  - Staves, sPHENIX production starts ~ January 2019, expect to last 6-12 months
- MVTX/INTT 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
- Cables
  - BNL approved the use of SamTec blue cables
    - Electrically better & mechanically compact
  - Signal and power cable samples ordered for mechanical global system integration mockup

Progress & Plan - II



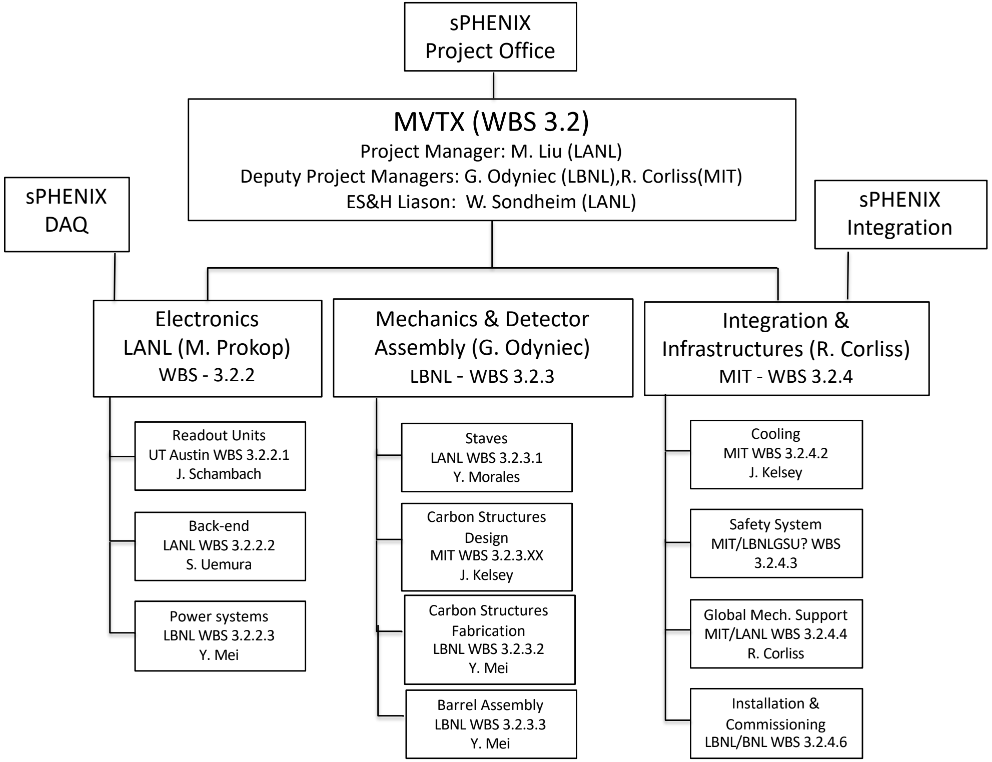
- Preliminary design from CERN for stave transportation plates
  - To get quote soon for production at CERN

- MVTX/Tracking workfest @FSU, 12/5, 8,9
  - Project update, task, schedule & plan
  - Tracking and simulations
  - Update physics plots



sPHENIX MVTX Group: Institution Roles

- 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

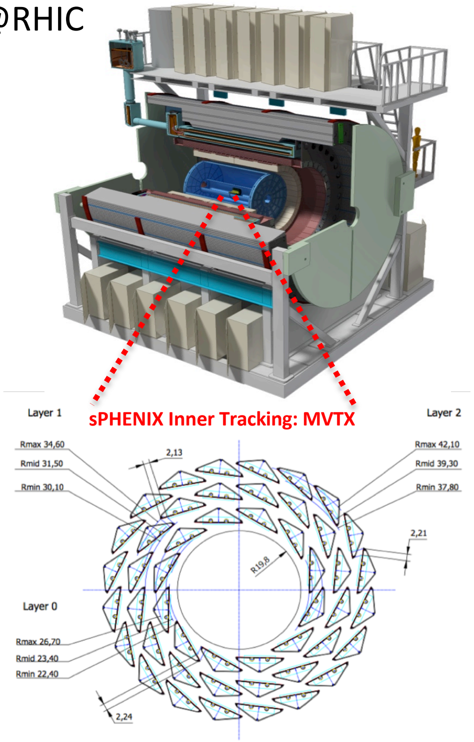
Summary: MVTX - WBS 3.2

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

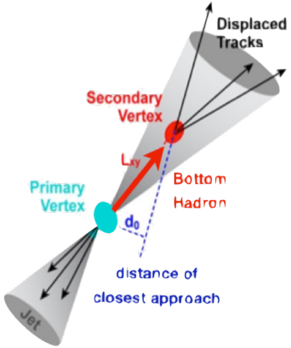
Backup slides

MVTX: MAPS-based VerTeX Detector

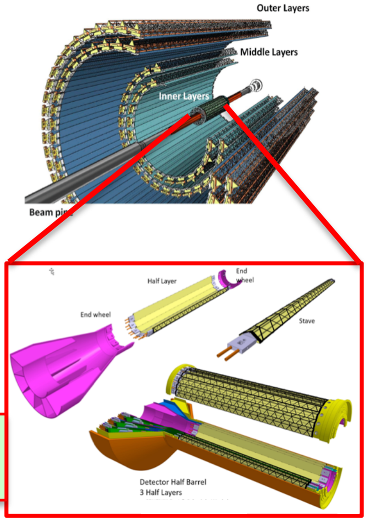
sPHENIX@RHIC (2023+)



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)

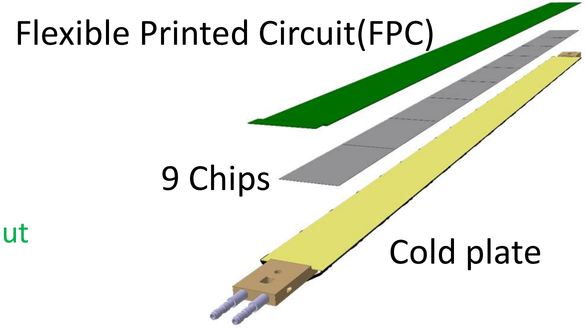
sPHENIX

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

Advantages of ALICE PIxel DEtector (ALPIDE) sensor:

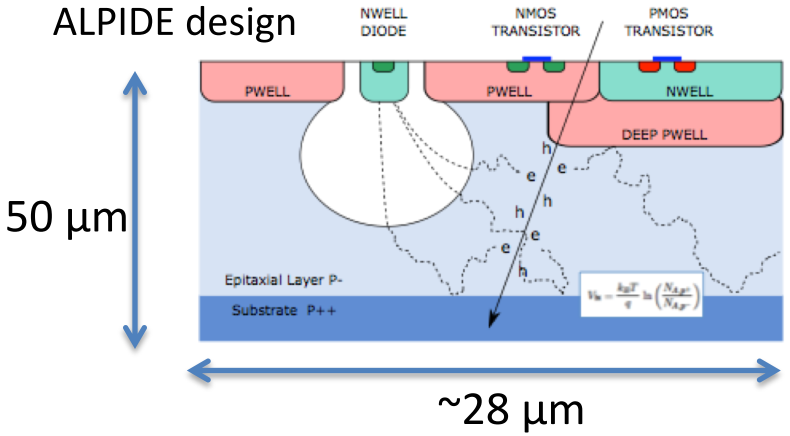
- Very fine pitch (27µm x 29µm), for superb spatial resolution
- High efficiency (>99%) and low noise (<10^{-6}), for excellent tracking
- Time resolution, as low as ~5 µs, for less pileup
- Ultra-thin/low mass, 50µm (~0.3% X_0), for less multiple scatterings
- 0.5M channels with on-pixel digitization,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

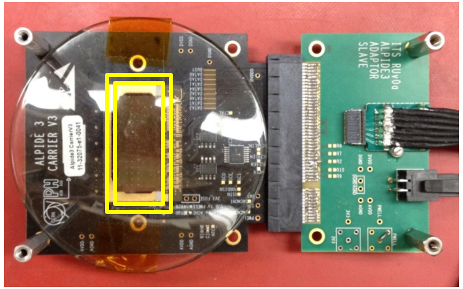


Tower Jazz 0.18 µm CMOS

- 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: $N_A \sim 10^{16}$

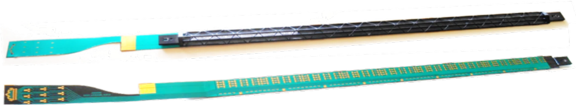
ALPIDE sensor:
1.5cm x 3.0cm, 0.5M channels



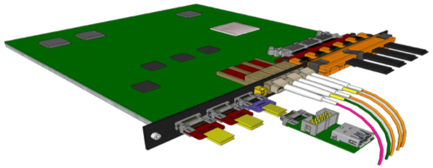
MVTX Sensors and Electronics Production

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)

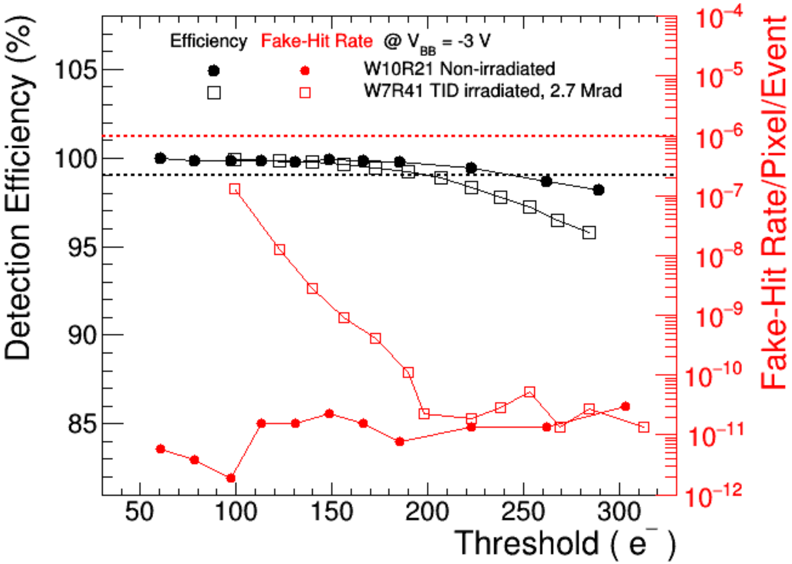
sPHENIX triggered data rate fits well within ALICE readout hardware specs

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/

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.

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})

Projected Radiation Level after 5-year Runs

sPHENIX

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]

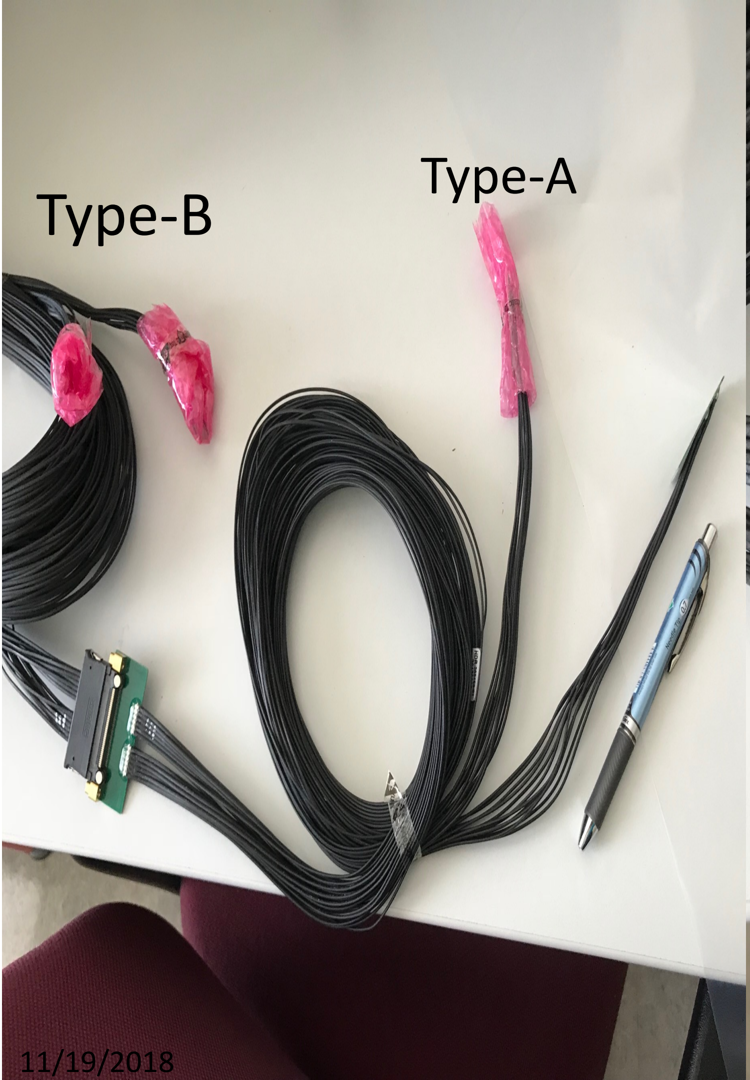
Projected sPHENIX MVTX L0 fluence: TID = 1060krad

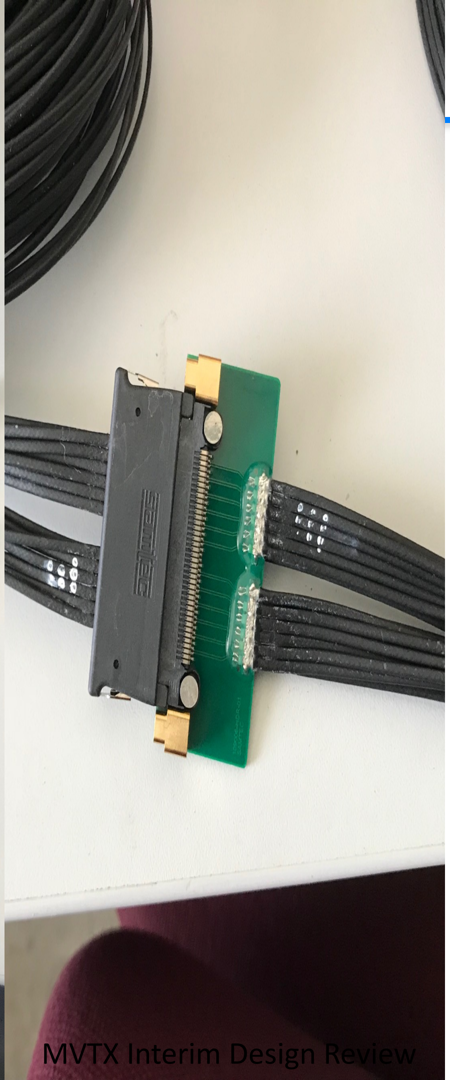
NIEL = $6x10^{12}$ N_{eq}/cm^2

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

Stave and RU Production QA Plan

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

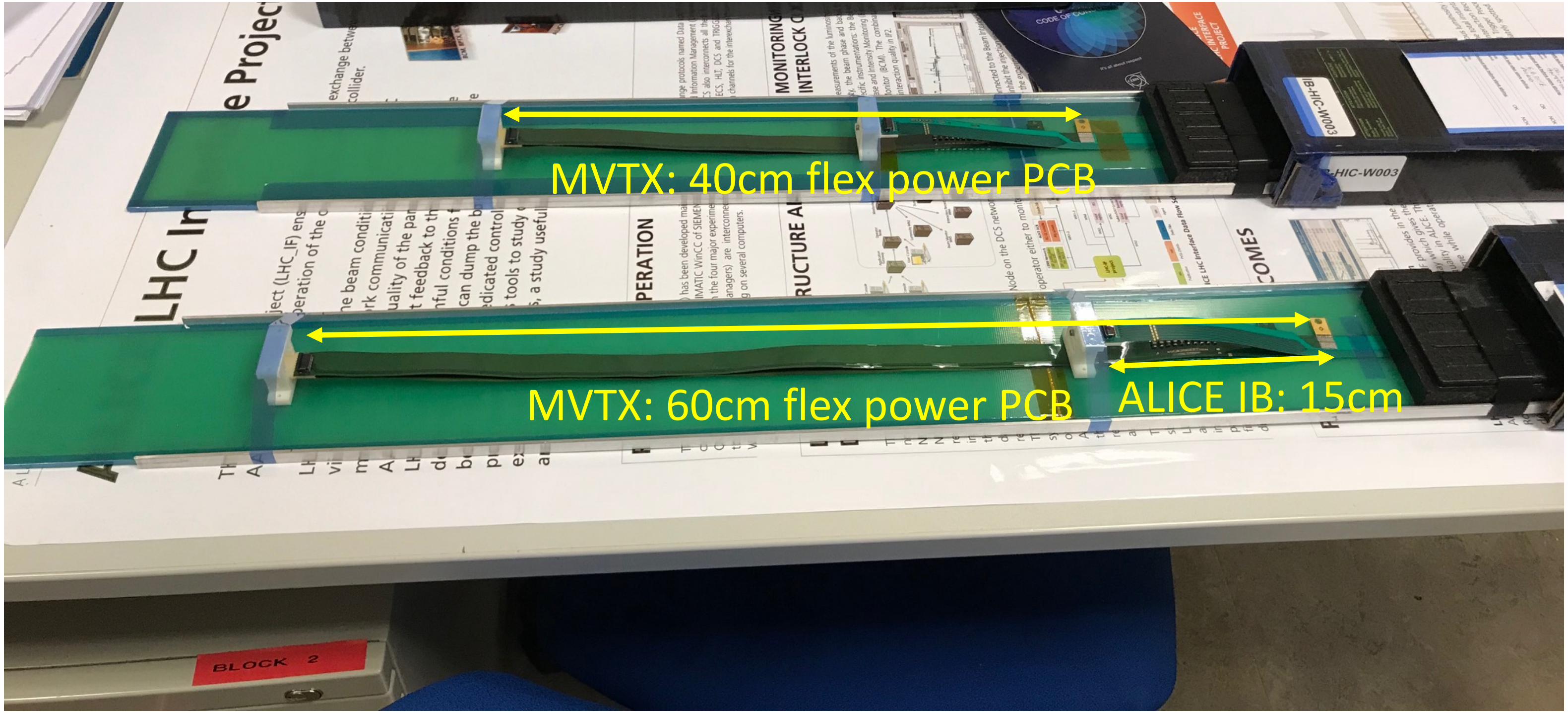
- Purchase 60 RUs from ALICE/CERN
  - 48 + 12 spares(20%)
  - To be part of ALICE production
    - Cost saving
    - Minimize technical risks
  - Initial test at CERN
- Acceptance QA at UT-Austin
  - Full test
  - LANL as the 2nd test site

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

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

NO noticeable difference in sensor performance, as expected

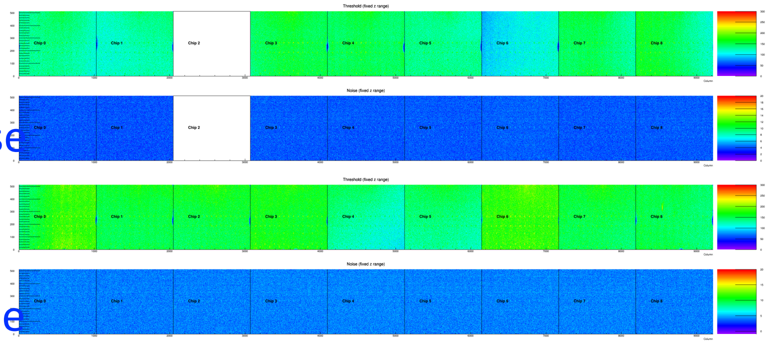


HICs Test Results from CERN

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

- 15 cm: **Before: 2 ALICE IB HICs**

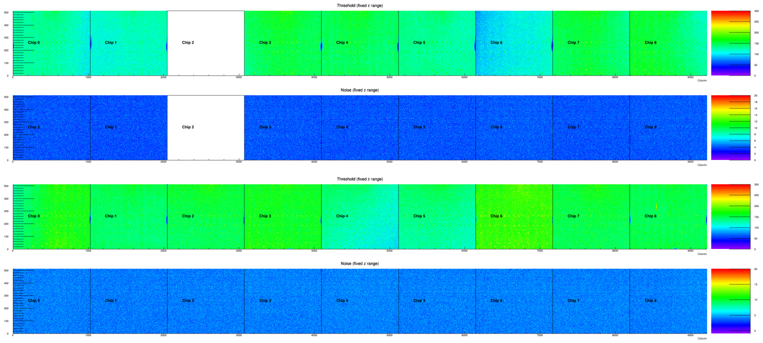
Thr.
Noise
Thr.
Noise



After: same ALICE HICs, replaced power FPCs

- top 40 cm, bottom 60 cm:

HIC1
HIC2



Chip-0 Chip-8

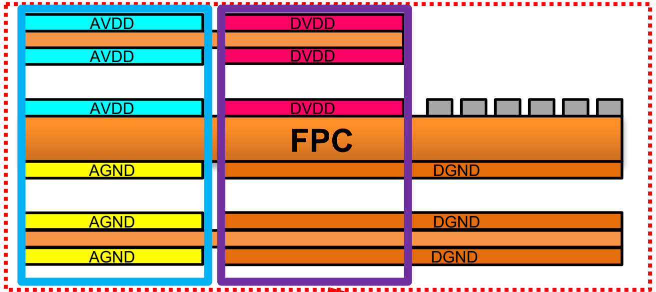
Noise level: ~4 e's; Threshold: ~180e's; MIP: ~1000 e's

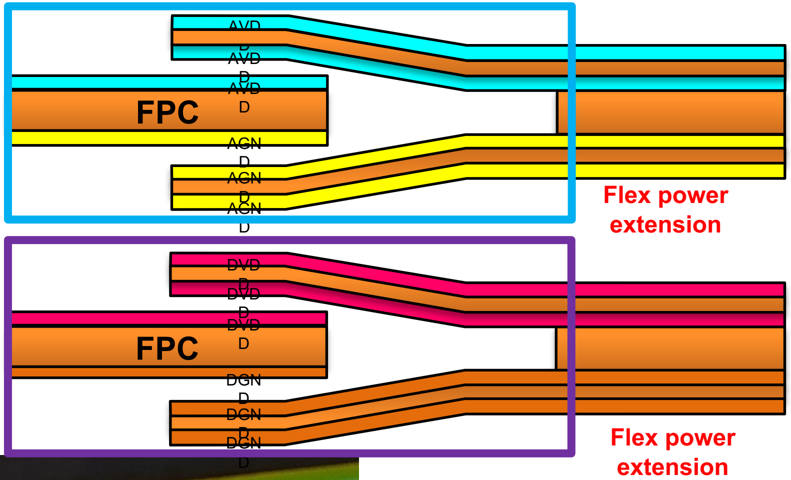
FPC Extension for Connection to Electrical Services

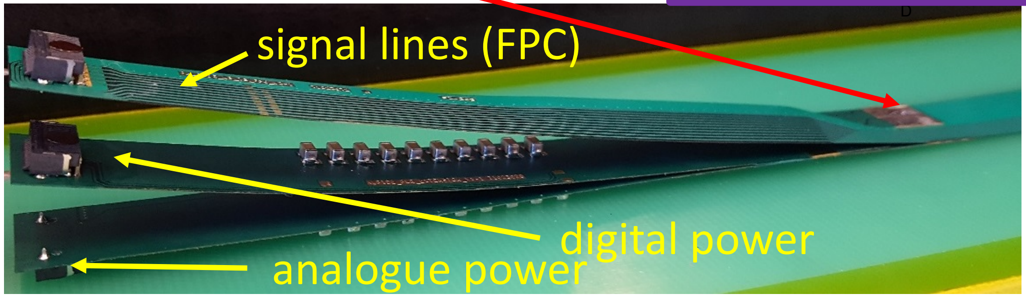
From Antonello Di Mauro

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







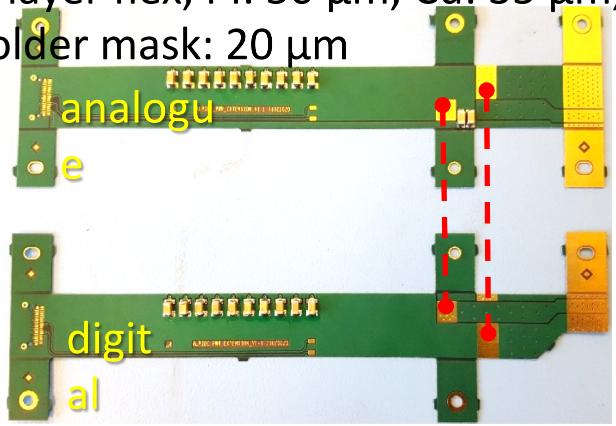
Modified for sPHENIX: 15cm -> 40cm

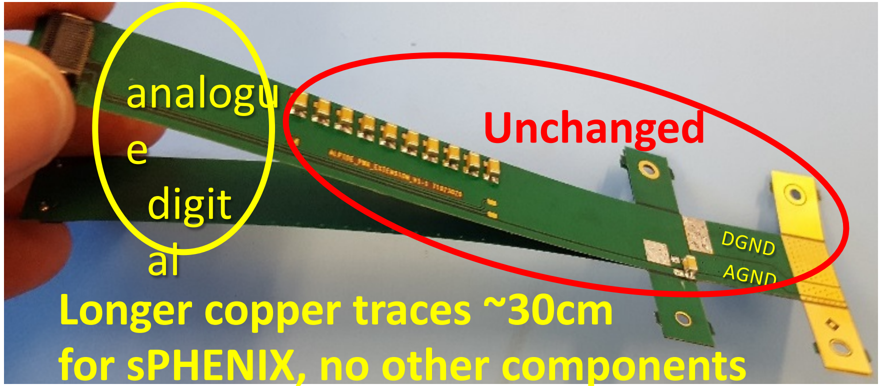
FPC Extension for Connection to Electrical Services

From Antonello Di Mauro

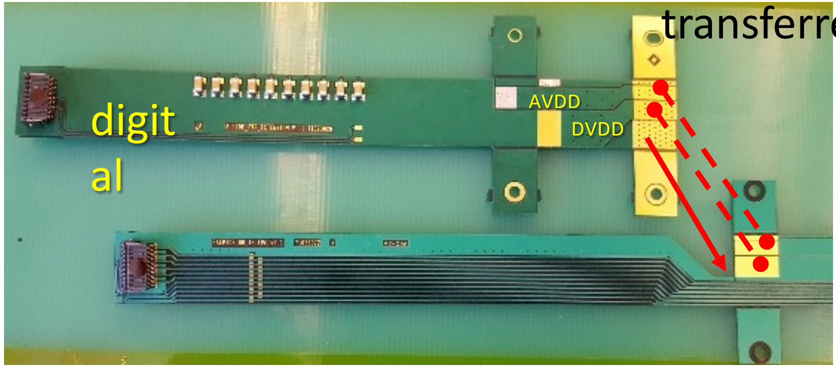
ALICE ITS Upgrade

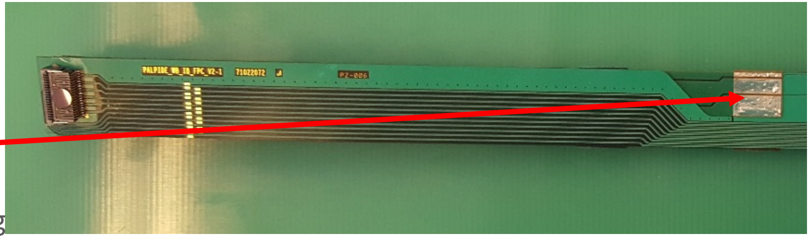
2-layer flex, PI: 50 µm, Cu: 35 µm, solder mask: 20 µm





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