MVTX Overview (WBS 3.2)

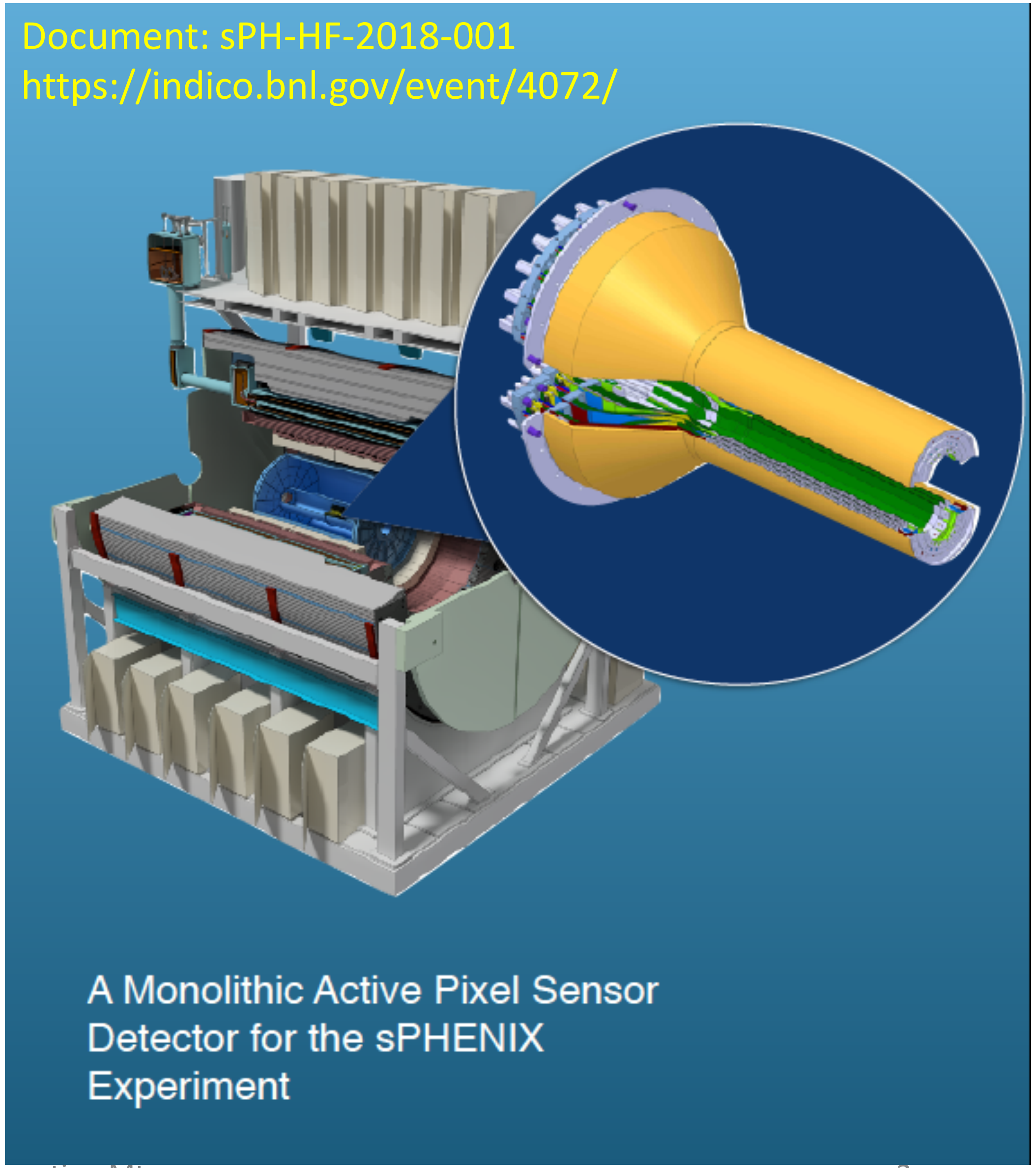
Ming X. Liu
Los Alamos National Laboratory

sPHENIX Collaboration Meeting @NCU

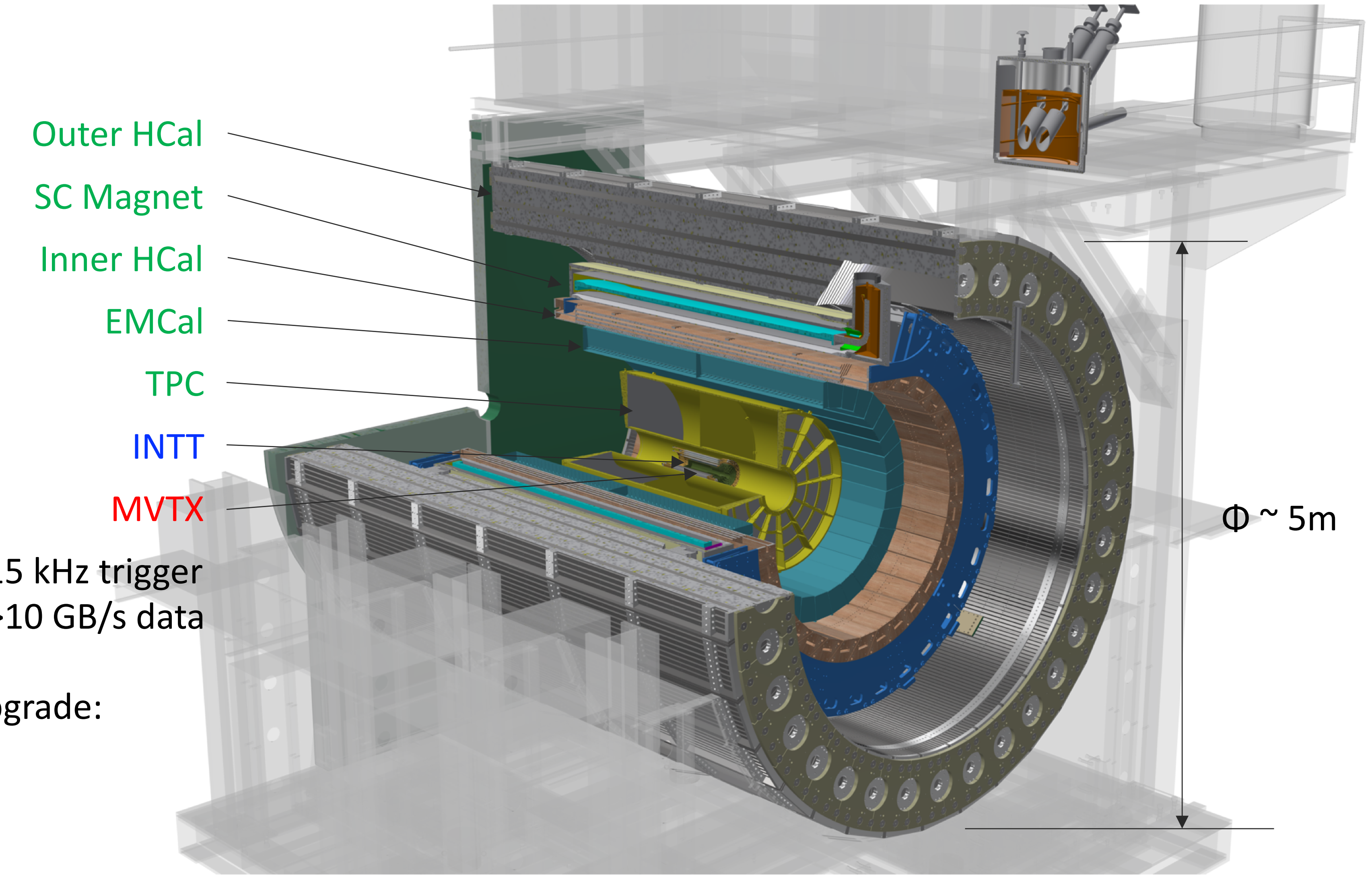
03/25-27,2019

Outline

- MVTX science & technology
- Recent reviews and R&D progress
  - LBNL MVTX/HF workshop highlights
- MVTX project status
  - Near term plan and to-do list



The sPHENIX Detectors



15 kHz trigger
>10 GB/s data

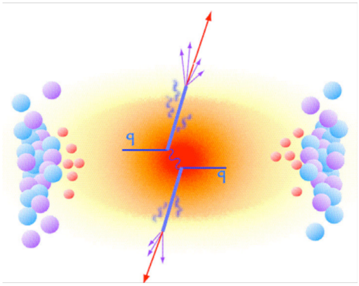
Tracking system upgrade:
- MVTX (WBS3.2)
- INTT (WBS3.1)

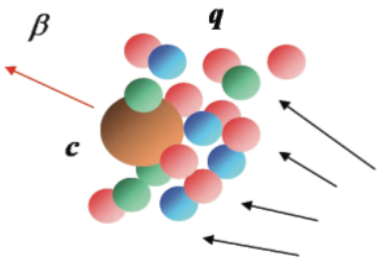
MVTX Enables the 3rd Science Pillar

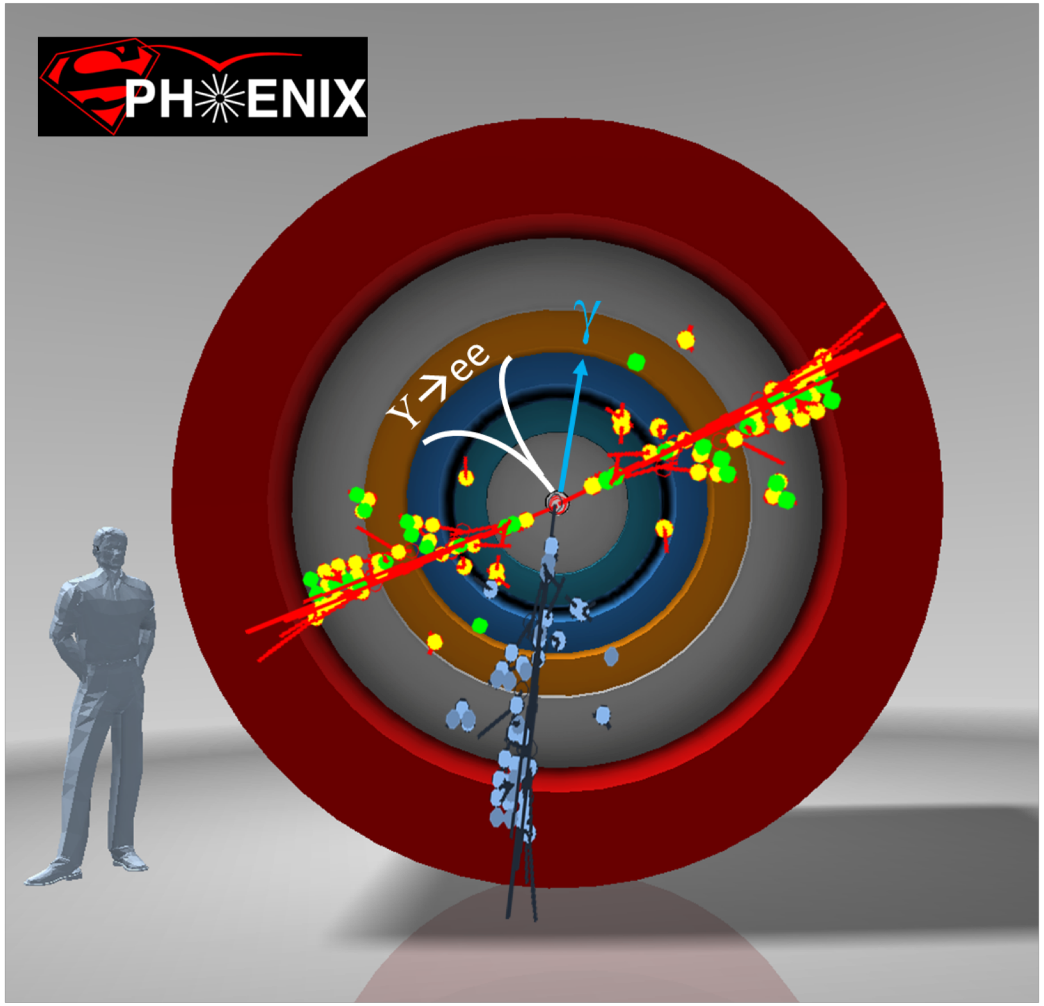
Jin/Xin's talk

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
- Access fundamental transport properties of QGP







Dave's talk from this morning

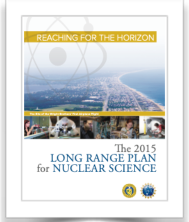
(G. Roland, CERN REC presentation)

Complementarity of LHC and sPHENIX for QGP studies

There are two central goals of measurements planned at RHIC, as it completes its scientific mission, and at the LHC: **(1) Probe the inner workings of QGP by resolving its properties at shorter and shorter length scales. The complementarity of the two facilities is essential to this goal, as is a state-of-the-art jet detector at RHIC, called sPHENIX. (2) Map the phase diagram of QCD with experiments planned at RHIC.**

"This programme after LS2 includes precision studies of the **flow of heavy quarks and of open heavy flavor and quarkonia** production , the detailed analysis of fluctuations of conserved charges and of **quenched jet fragmentation via high statistics photon/Z-jet correlations,** and access to signals of electromagnetic radiation from the dense medium. This will enable to fully establish the long-wavelength matter properties of the plasma produced at the LHC, and to get **access to the partonic dynamics that underlies the observed surprisingly strong collective phenomena. "**

"As the **temperature dependence of transport properties** can be accessed experimentally by varying the center of mass energy over a logarithmically wide range, the **combined analysis of LHC data and future high precision data from RHIC** offers a qualitatively novel handle on the temperature dependence of properties of hot and dense matter. **The Town Meeting observes that the recently approved sPHENIX proposal targets these opportunities by bringing greatly extended capabilities to RHIC…**



2015 US NP LRP

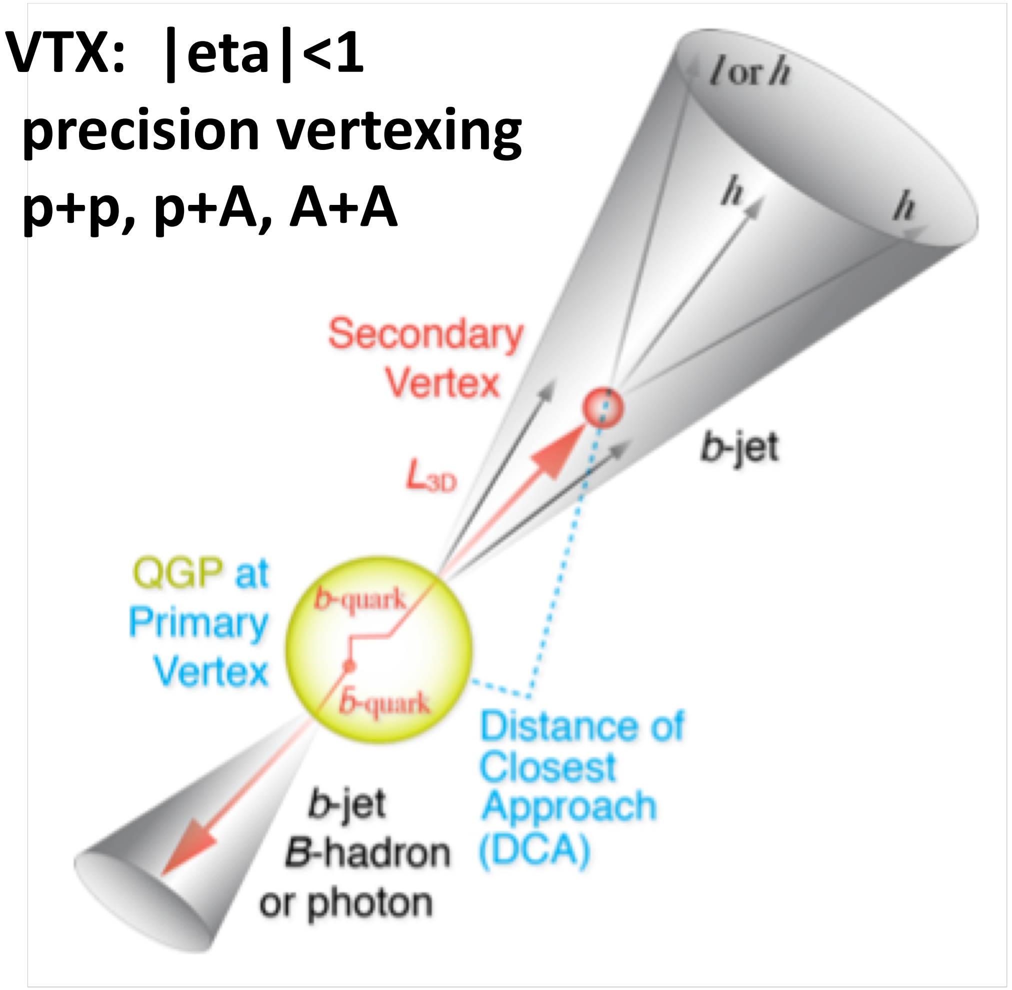
WG5 for 2019 ECFA document

MVTX Physics Highlights

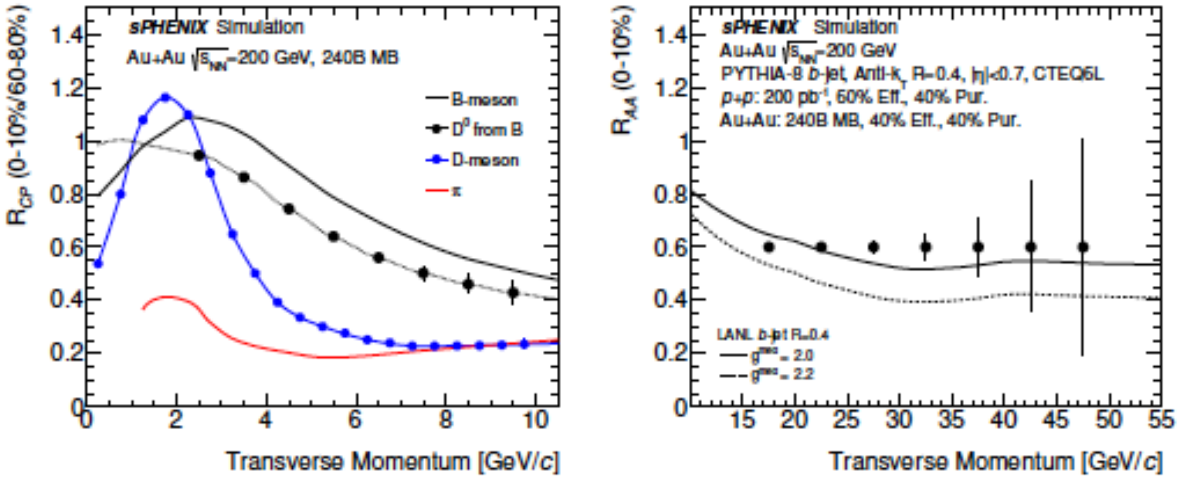
Jin/Xin's talk

MVTX: |eta|<1

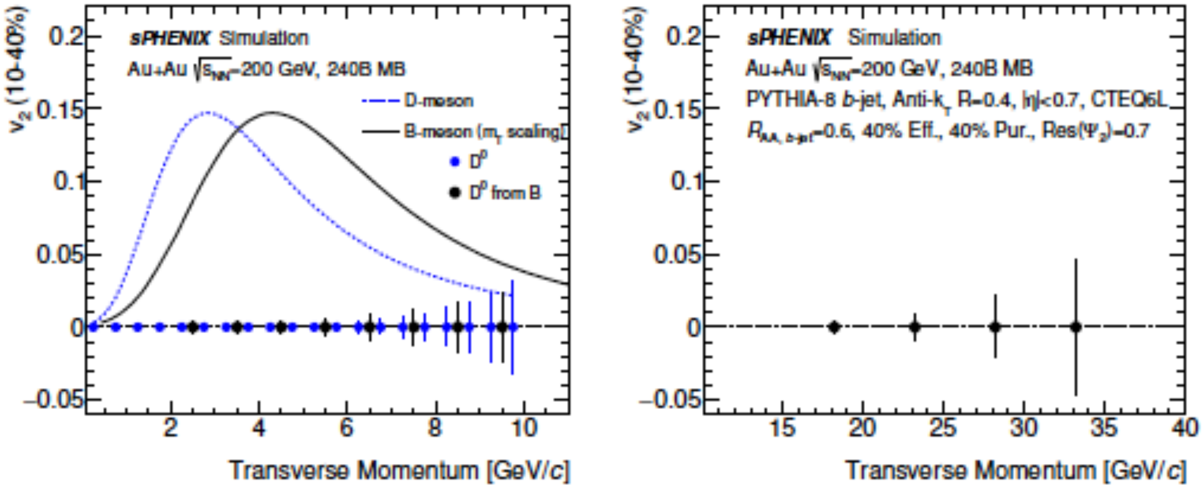
- **precision vertexing**
- **p+p, p+A, A+A**



"B meson and b-jet modification"



"B meson and b-jet flow"



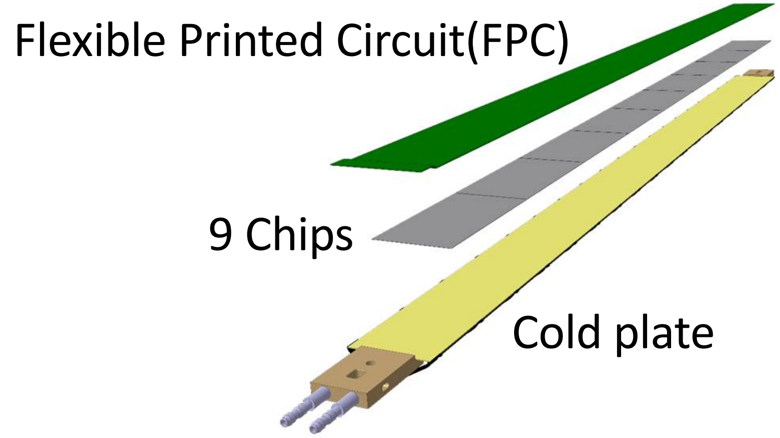
Monolithic Active Pixel Sensors (MAPS)

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

Advantages of ALICE PIxel DEtector (ALPIDE) sensor:

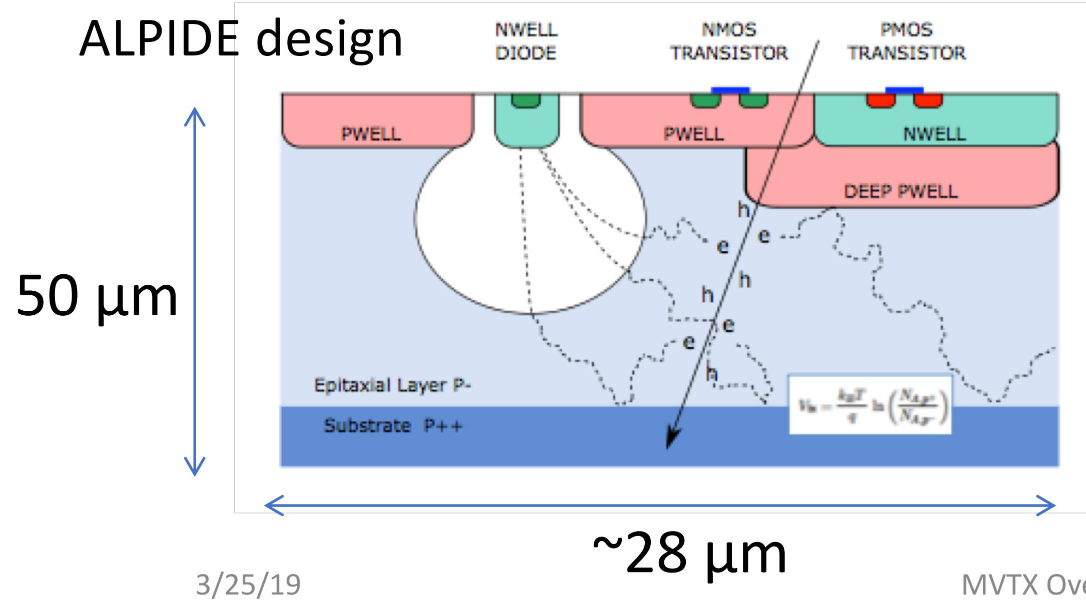
- Very fine pitch (27µm x 29µm), for superb spatial resolution
- High efficiency (>99%) and low noise ($<10^{-6}$), for excellent tracking
- Time resolution, as low as ~5 µs, for less pileup
- Ultra-thin/low mass, 50µm (~0.3% X_0), for less multiple scatterings
- 0.5M channels with on-pixel digitization, for zero-suppression and fast readout
- Low power dissipation, 40mW/cm², for minimal service materials

An ideal detector for QGP physics!



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

ALPIDE design

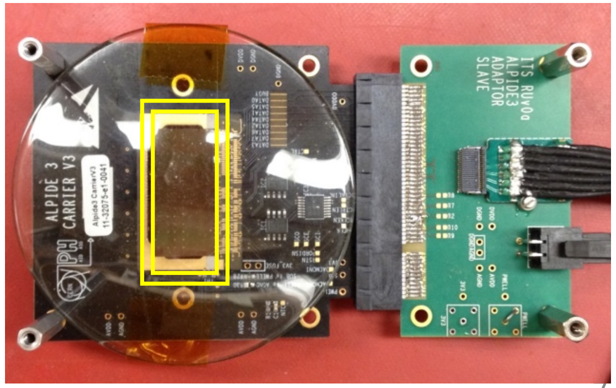


Tower Jazz 0.18 µm CMOS

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

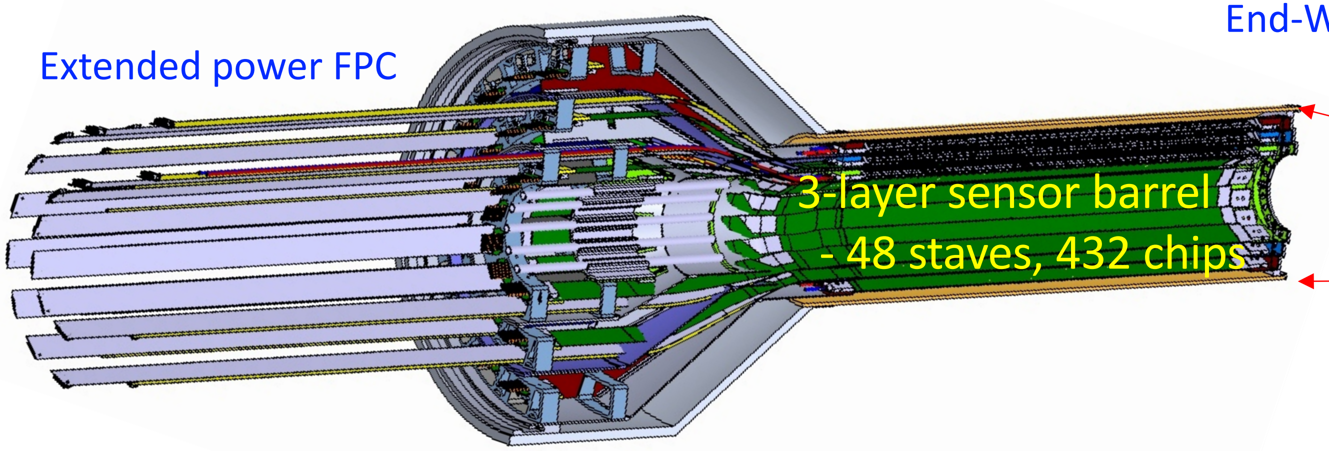
ALPIDE sensor:
1.5cm x 3.0cm, 0.5M pixels

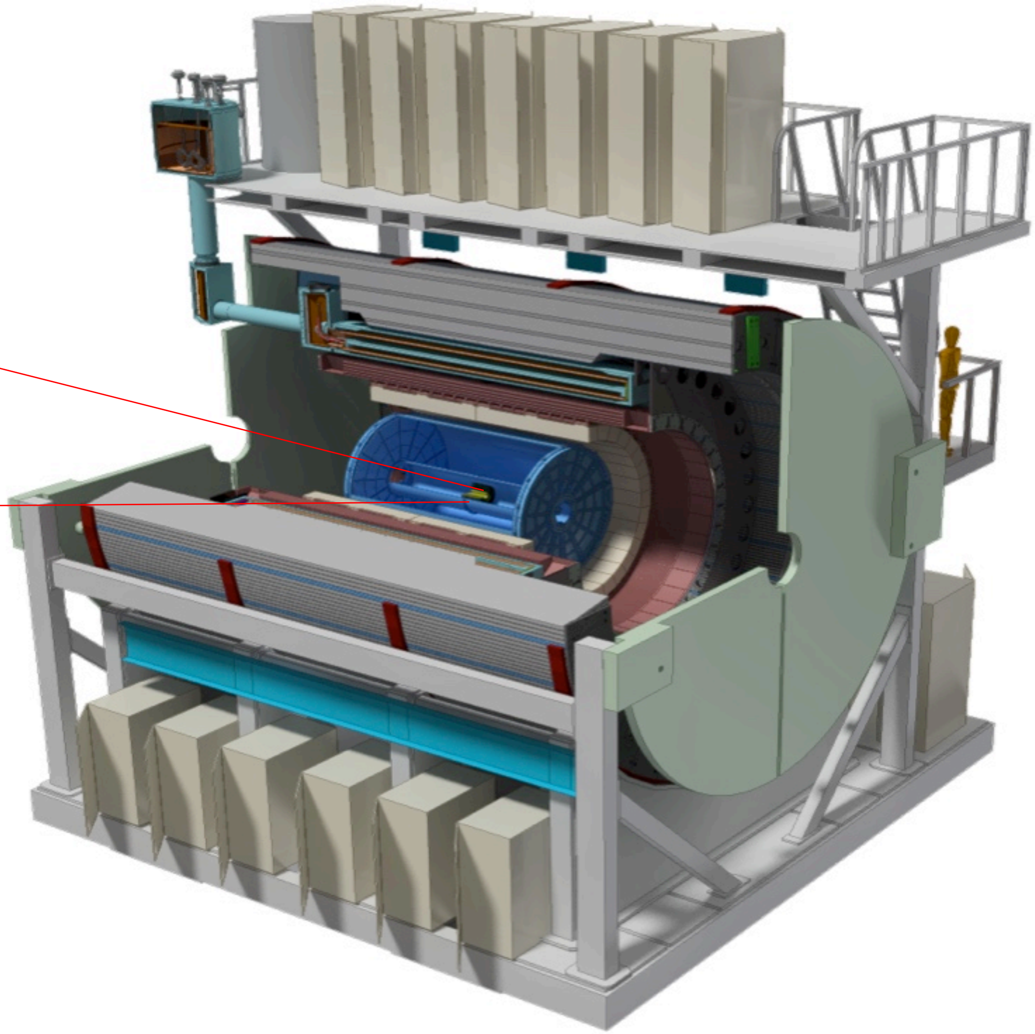


MVTX Detector – Modified from ALICE/ITS Design

Ross' talk

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

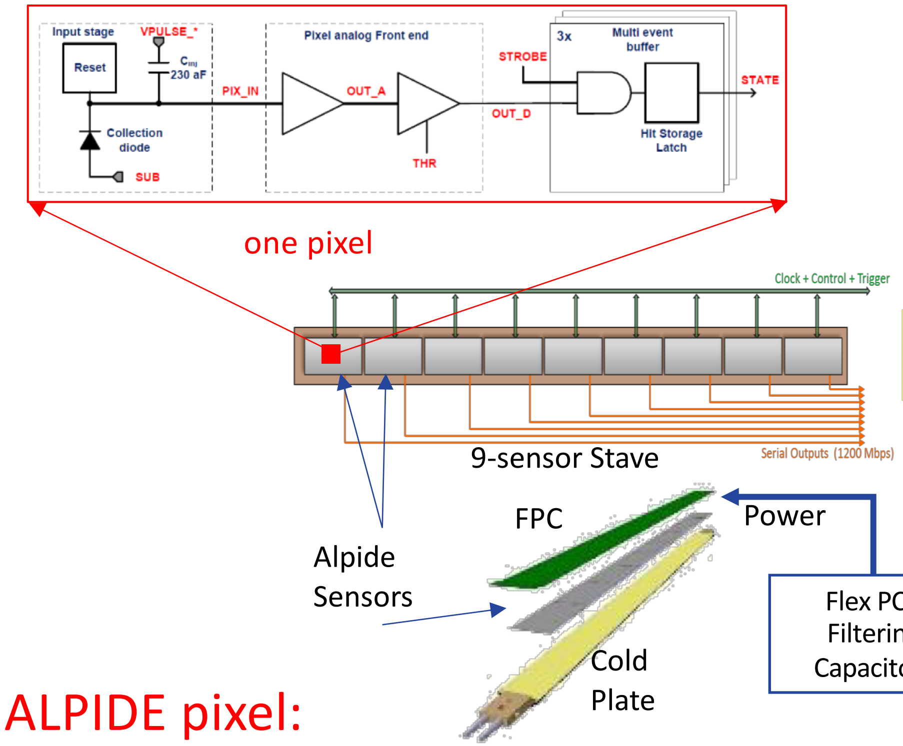
Scope of the MVTX Project

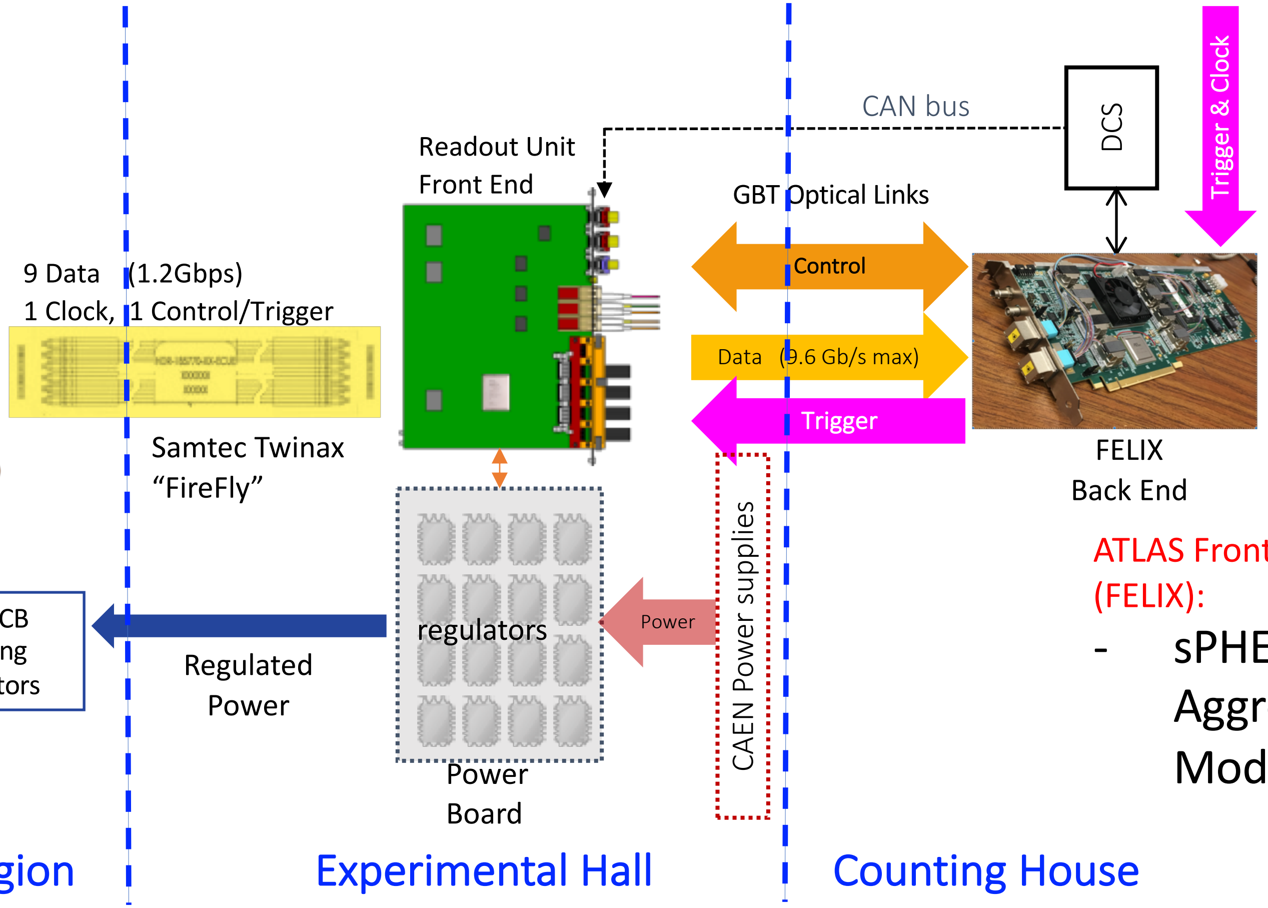
- MAPS Staves & Electronics
  - Readout Integration R&D (LANL LDRD)
    - Frontend: ALICE/ITS, RU
    - Backend: ATLAS FELIX
    - Reprogram RU & FELIX into RCDAQ/sPHENIX
  - Production @CERN: $1.36M
    - 84 ALICE/ITS-IB staves from CERN
      - Acceptance test @LBNL, 48+spares(2-inner layers+)
    - 60 ALICE/ITS-RU from CERN
      - Acceptance test @UT-Austin, 48+spares(12)
  - **Production & Assembly @US: ~$5M**
    - Production QA & assembly
      - Half detector assembly & test @LBNL
      - FELIX test & integration @LANL/BNL, 6+spares(2)
    - Ancillary systems
      - “adopt” ALICE ITS system
      - Power, slow control & monitoring etc.

- Mechanics & Cooling
  - Modify ALICE/ITS inner tracker mechanical structures
    - End Wheels
    - Cylindrical structure shells
    - Detector half barrels
    - Detector and Service half barrels
  - Mechanical system integration,
    - Conceptual design (LANL LDRD)
    - Design & simulations, MIT/LANL
    - Composite structure production, LBNL
    - Non-composite structure, MIT
    - Installation tooling etc., BNL/LANL/MIT/LBNL
  - Adopt ALICE cooling plant design
    - Modifications to fit sPHENIX, MIT/BNL

Final test @BNL, Installation & commissioning (BNL + MVTX group)

MVTX Readout, Power and Controls





- Slow control Mike's talk

ATLAS Front-End Link eXchange (FELIX):

- sPHENIX Data Aggregation Module(DAM)

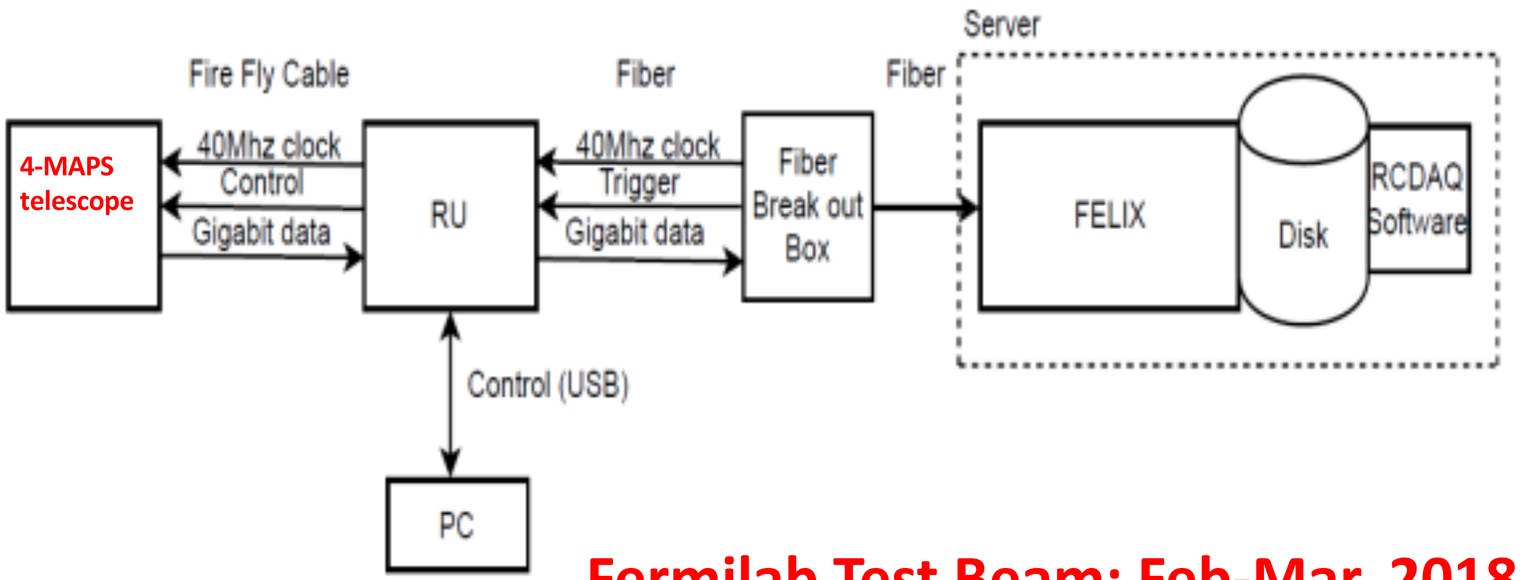
ALPIDE pixel:

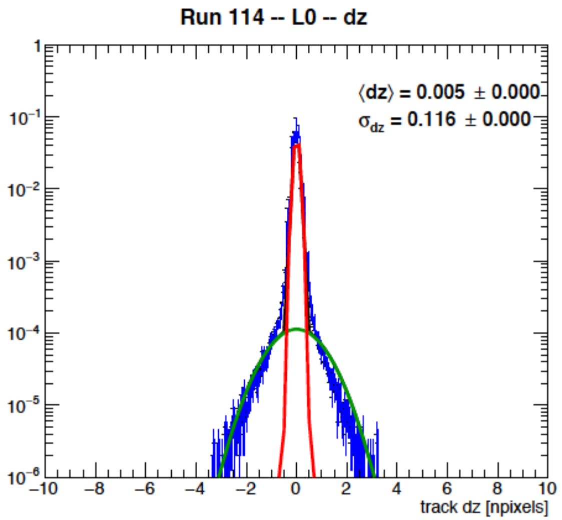
- Shaping
- Digitization
- Zero-suppression
- 3x buffer

MVTX Detector Electronics consists of three parts

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

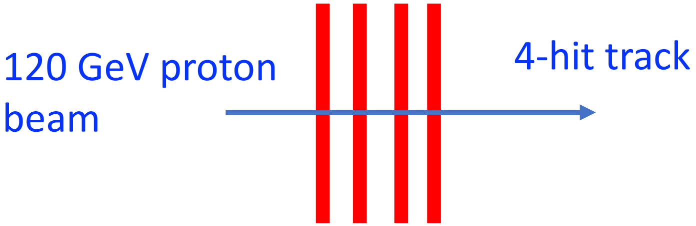
MVTX Full Readout Chain Demonstrated (3/2018)





Tracking spatial resolution achieved: <5 um

Fermilab Test Beam: Feb-Mar, 2018



4-MAPS telescope

Highlights from Recent Reviews and R&D

- July 2018 Stave and RU Production Readiness Review
- November 2018 mechanical system integration review
- April 2019 Review : "CD-1 equivalent"

The Tracking System Upgrades consist of a silicon strip detector provided as an in-kind contribution by RIKEN, and a vertex detector using state-of-the-art Monolithic Active Pixel Sensors. The tracking systems are ready for a "CD-1 equivalent" review.

Stave and RU Procurement Readiness
BNL Director's Review, 7/19-20, 2018

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

- To produce RU and staves as part of ALICE production
  - Reduce technical risks
  - Cost saving
- To meet sPHENIX installation & run schedule.

DAY-1 PHYSICS

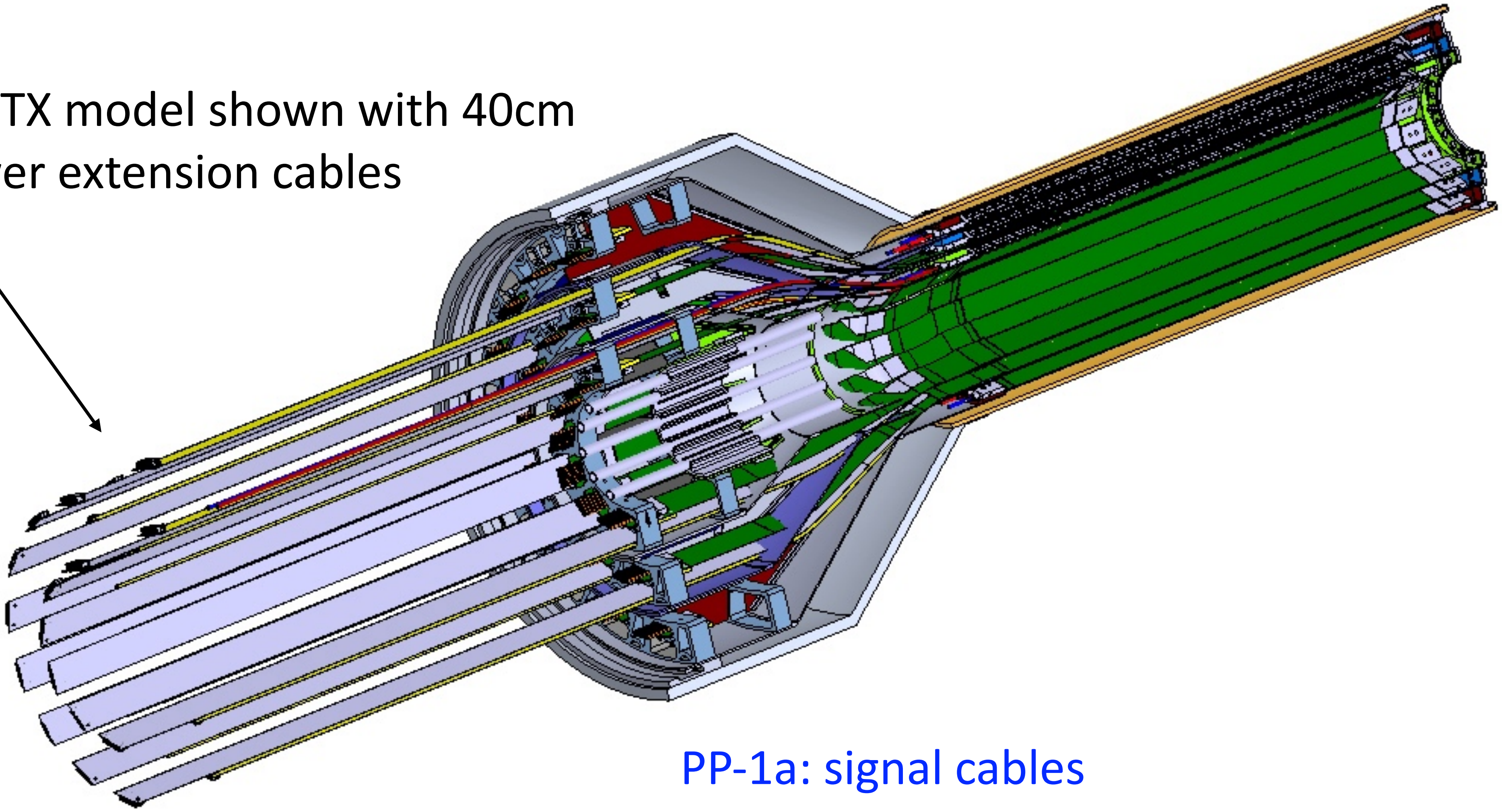
Recommendations:

1) RU, proceed with production
2) Resolve MVTX/INTT space conflict
   1) modify stave design, longer power cables
   2) build a 3-D model
   3) Simulation TF to optimize INTT layers
3) Stave radiation hardness

MVTX/INTT Mechanical Integration – Stave Modification

Ross' talk

This MVTX model shown with 40cm flat power extension cables

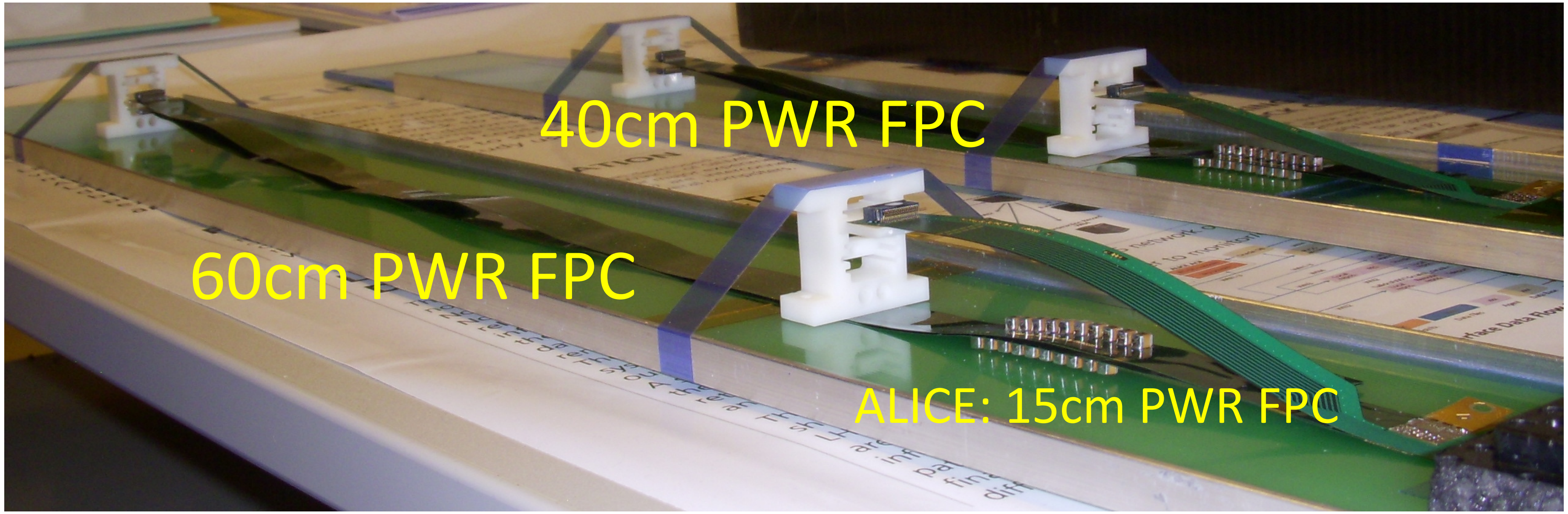


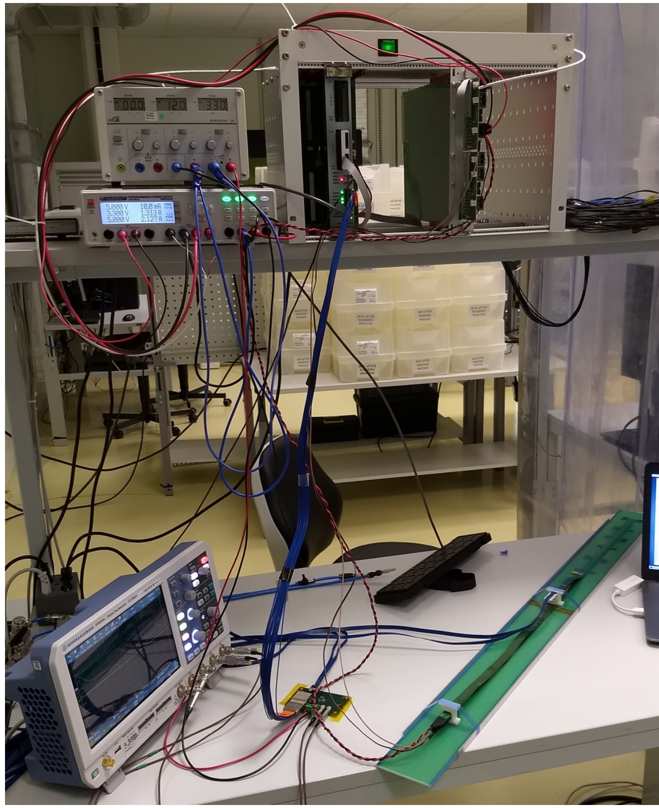
PP-1a: signal cables

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;



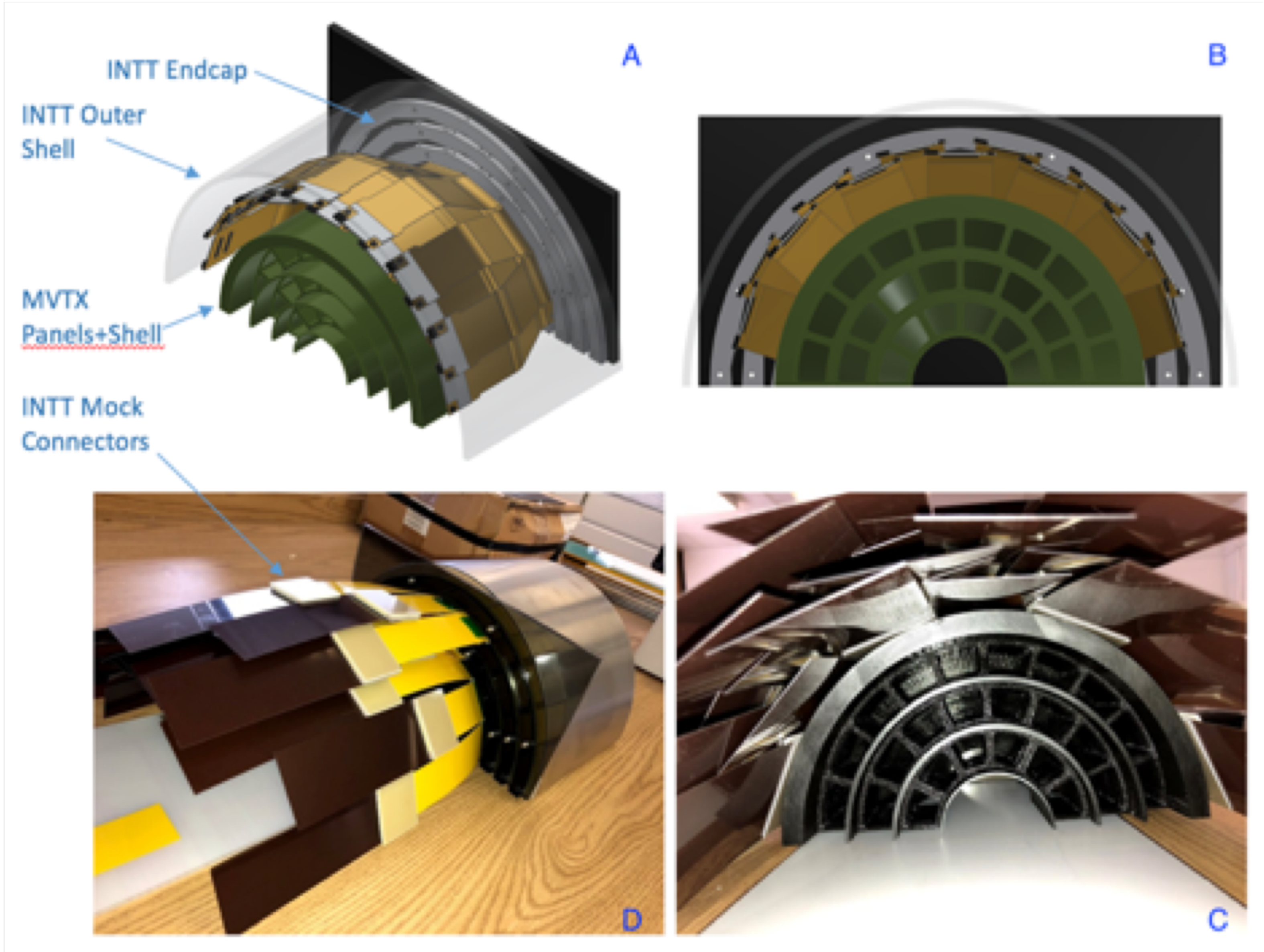


Details presented by Dr. Sho Uemura at the sPHENIX general meeting on 9/23/2018

Nice work by Alex and Sho et al!

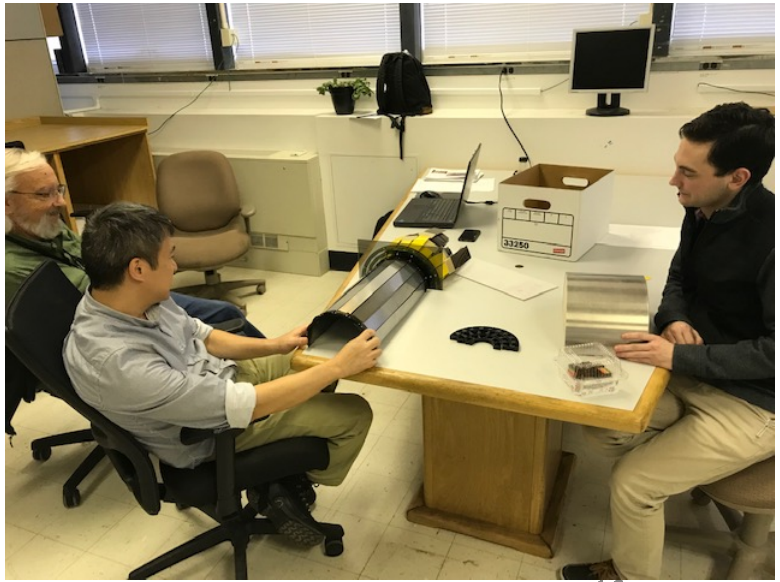
Followed identical ALICE IB QA test procedure, with a 8m SamTec cable!

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!

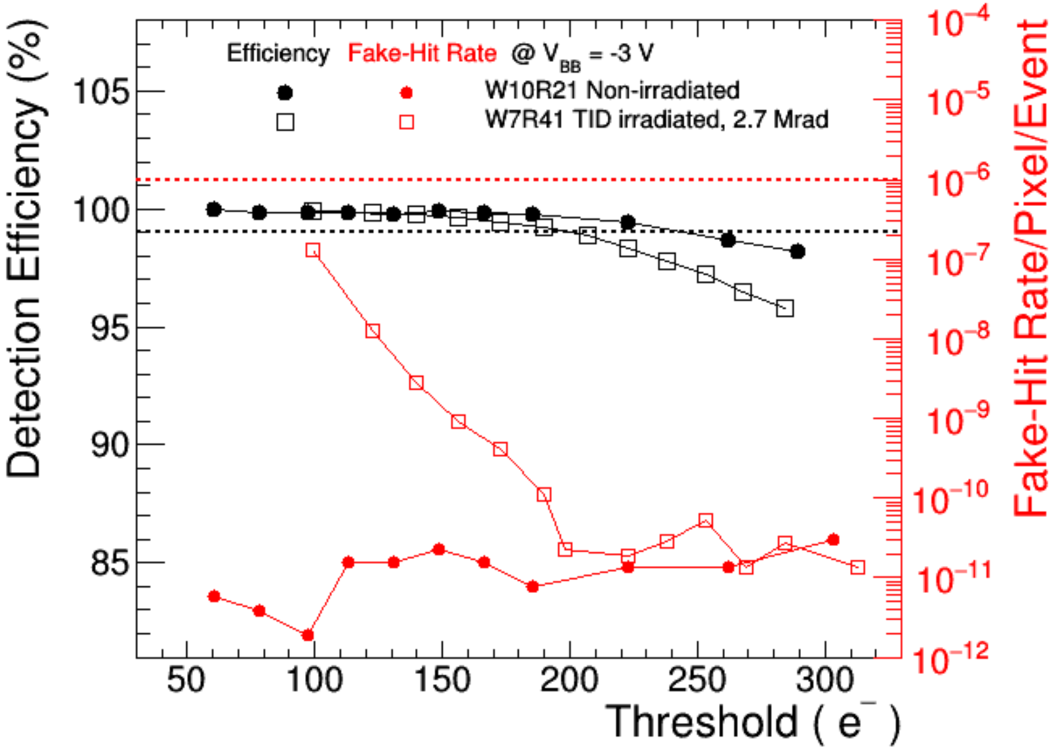


Sensor Irradiation Test – OK at 2.7MRad

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

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

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})

Address July 2018 Review Recommendations

Stave and RU procurement readiness

- Completed sensor/HIC/stave evaluations at CERN
  - Built, tested and confirmed two HICs with 40cm and 60cm long power FPC
  - Sensors irradiated up to 2.7MRad, no issues (updated 9/18/2018).
- **Addressed all recommendations on stave/sensor R&D**

  https://docs.google.com/document/d/1vsm_G7ZLgqv-kBZqK0jF69T_Nx2Uwk0Zxv86jRVxybw/edit?usp=sharing
- **Cost are set for staves & RUs, procurement through US-ALICE/UTK!**
  - Technical specs document completed for production, BNL/DOE agreed
  - sPHENIX RU and stave production starts ~April 2019, practically already in progress
- MVTX/INTT mechanical integration
  - Mechanical design being updated and 3-D mockup demonstrated
  - Inner tracking task force completed evaluation, preferred INTT-layers =2

Christof, Rachid, Itaru's talks

- Readout cables
  - BNL approved the use of SamTec blue cables
    - Electrically better & mechanically compact
    - ALICE confirmed signal performance with 8m long readout cables. For MVTX, 10m very likely works (30AWG/sPHENIX vs 32AWG/ALICE), to be confirmed by on-going R&D at LANL
  - Samples ordered for system integration mockup and test

MVTX Design Interim Review

11/19/2019, led by John Haggerty

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

- Detector assembly & installation in sPHENIX

No evident showstoppers

Interim design review report, draft

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.

Ross' talk

MVTX Interim Design Review

Monday Nov 19, 2018, 1:00 PM → 4:00 PM US/Eastern

2-219 (BNL 510)

Description

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For those at BNL we will meet in 2-219
To join the Meeting: https://bluejeans.com/822435626
To join via Browser: https://bluejeans.com/822435626/browser
To join with Lync: https://bluejeans.com/822435626/lync
To join via Cisco Jabber Video: https://bluejeans.com/822435626/jabber
To join via Room System: Video Conferencing System: bjn.vc -or-199.48.
To join via phone :
1) Dial: +1.408.740.7256
            +1.888.240.2560
             +1.408.317.9253
              (see all numbers - http://bluejeans.com/numbers)
2) Enter Conference ID : 822435626
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charge.pdf

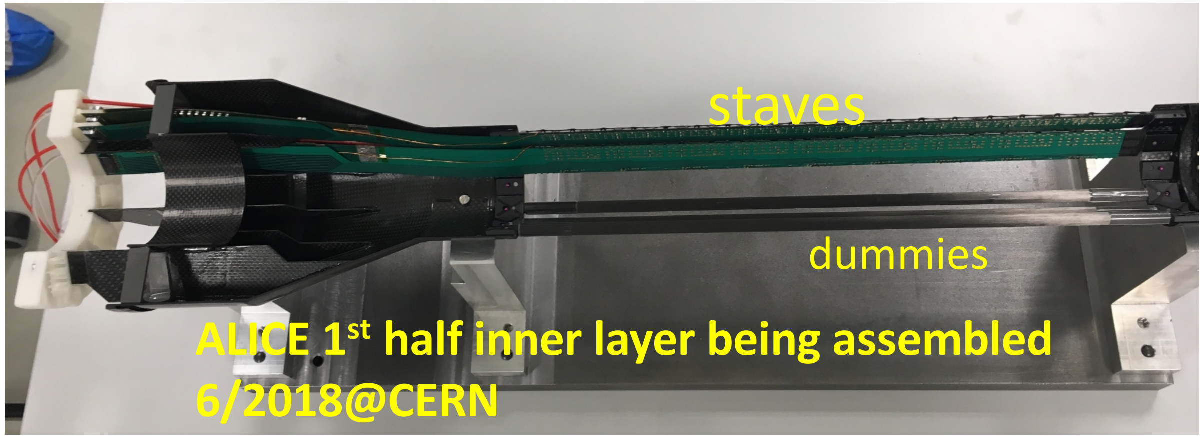
1:00 PM → 1:20 PM **Scope and Overview**
Speaker: Ming Liu (Los Alamos)
MVTX-Overview-Inte... | Scope and Overview

1:20 PM → 1:40 PM **Electronic Components**
Speaker: Sho Uemura (Los Alamos National Laboratory)
electronics.pdf

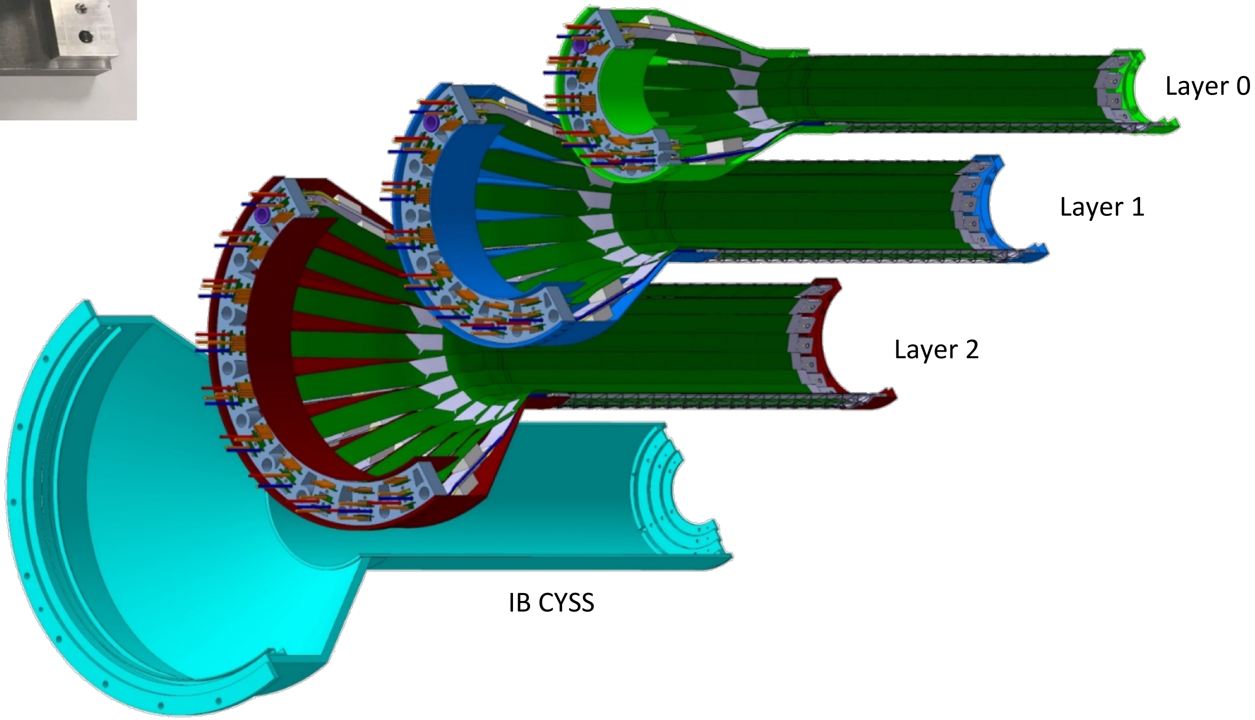
1:40 PM → 2:20 PM **Mechanical Components and Installation**
Speaker: Walter Sondheim (Los Alamos National Laboratory)
Walter-MVTX-interi...

> "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."

Detector Assembly & QA Plan at LBNL



Precision positioning and installation of staves on end-wheels

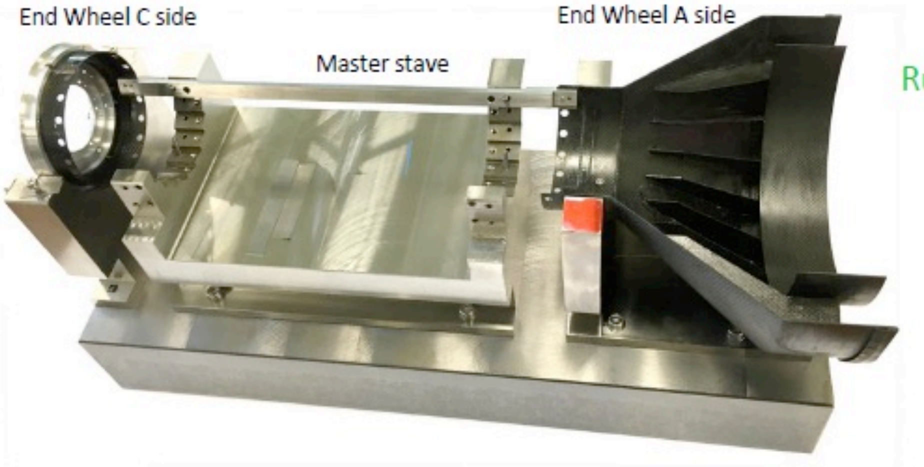


- Follow ALICE IB assembly procedures to build half-detectors for MVTX
- QA records in DB, travelers
- Modified jigs for MVTX
- Build two full half-barrel detector with the service structures

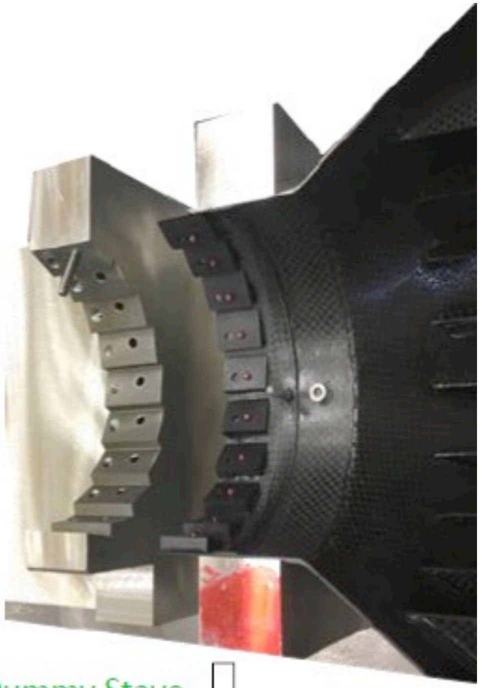
Install SamTec & power cables during half-barrel assembly with the service barrel at LBNL (under discussion)

IB Prototypes: Layer 2 Prototype

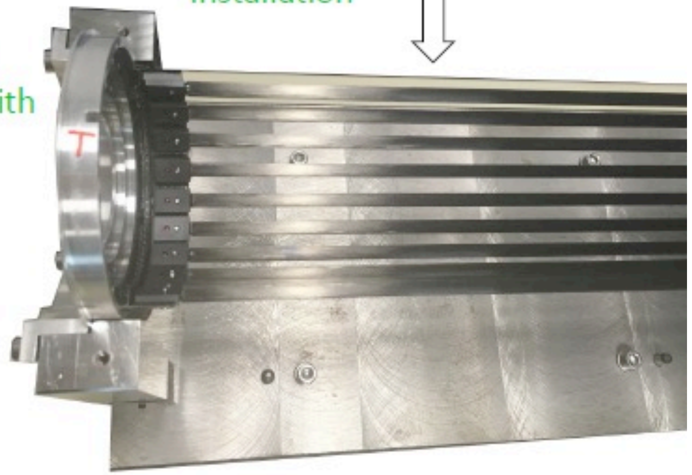
From ruby pads gluing to final stave installation procedure



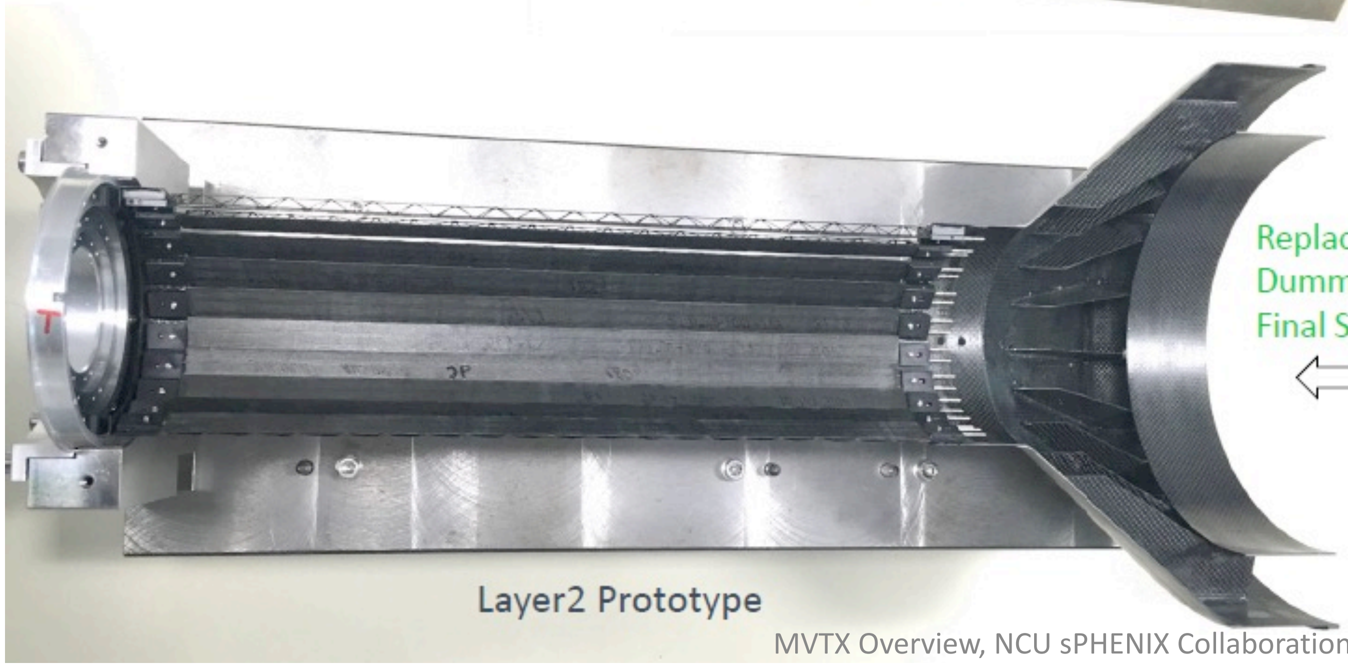
Ruby pads gluing



Dummy Stave installation



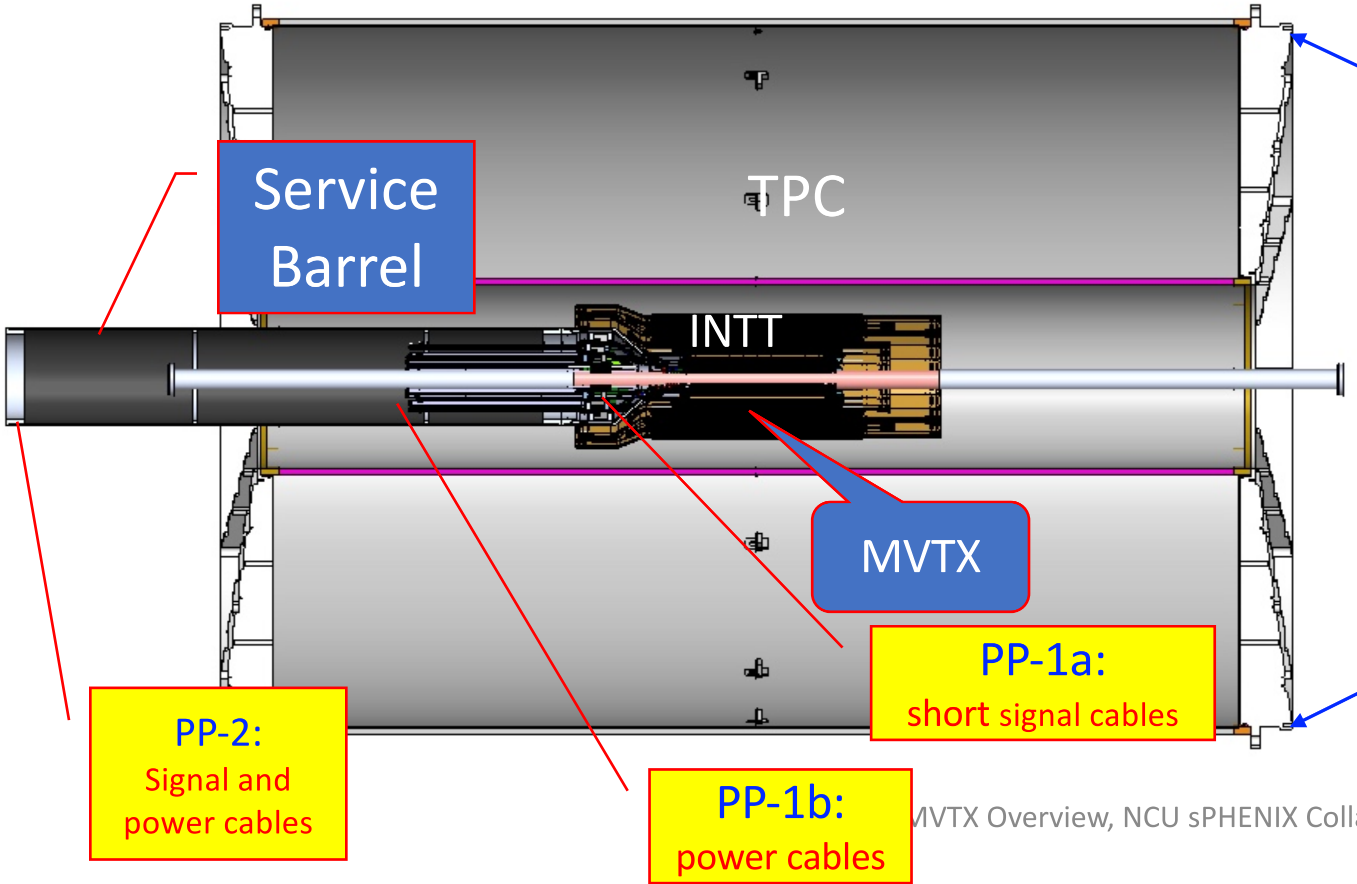
Replacement of Dummy Stave with Final Staves

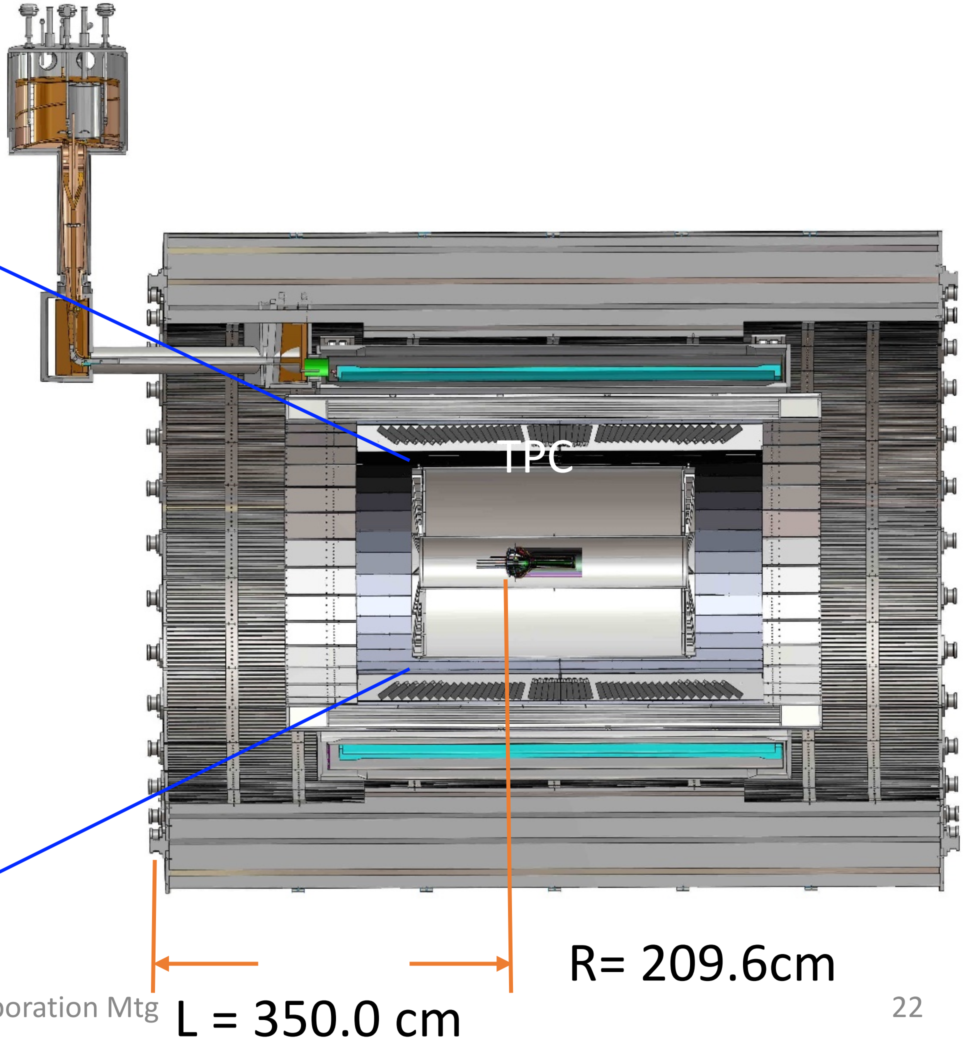


MVTX Global Mechanical System Integration

Ross' talk

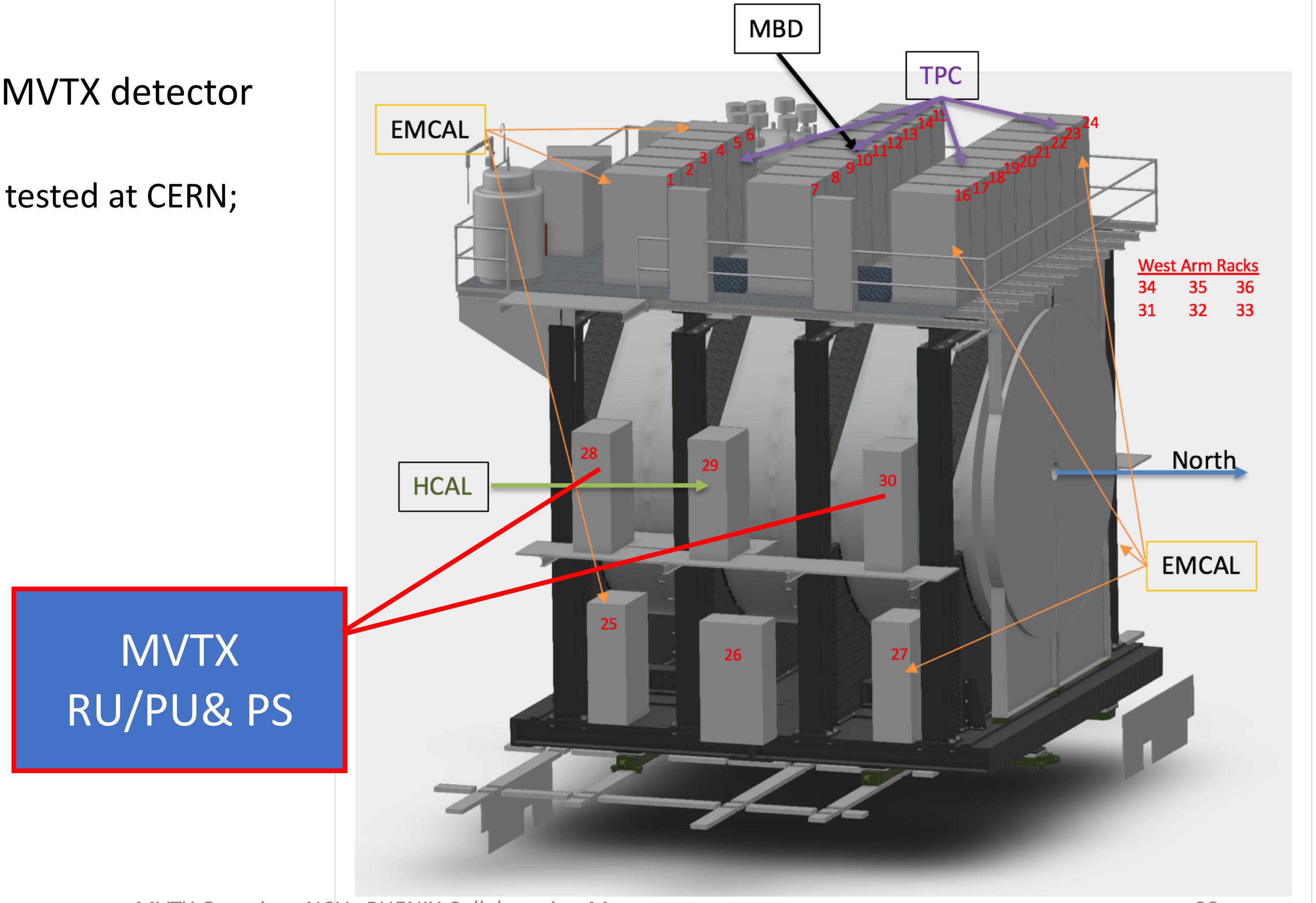
- MVTX service barrel preliminary design, with two parts:
  - Part-1: from MVTX to PP-1b, all power PCB, 40cm
  - Part-2: length TBD later, from PP-1b to PP-2



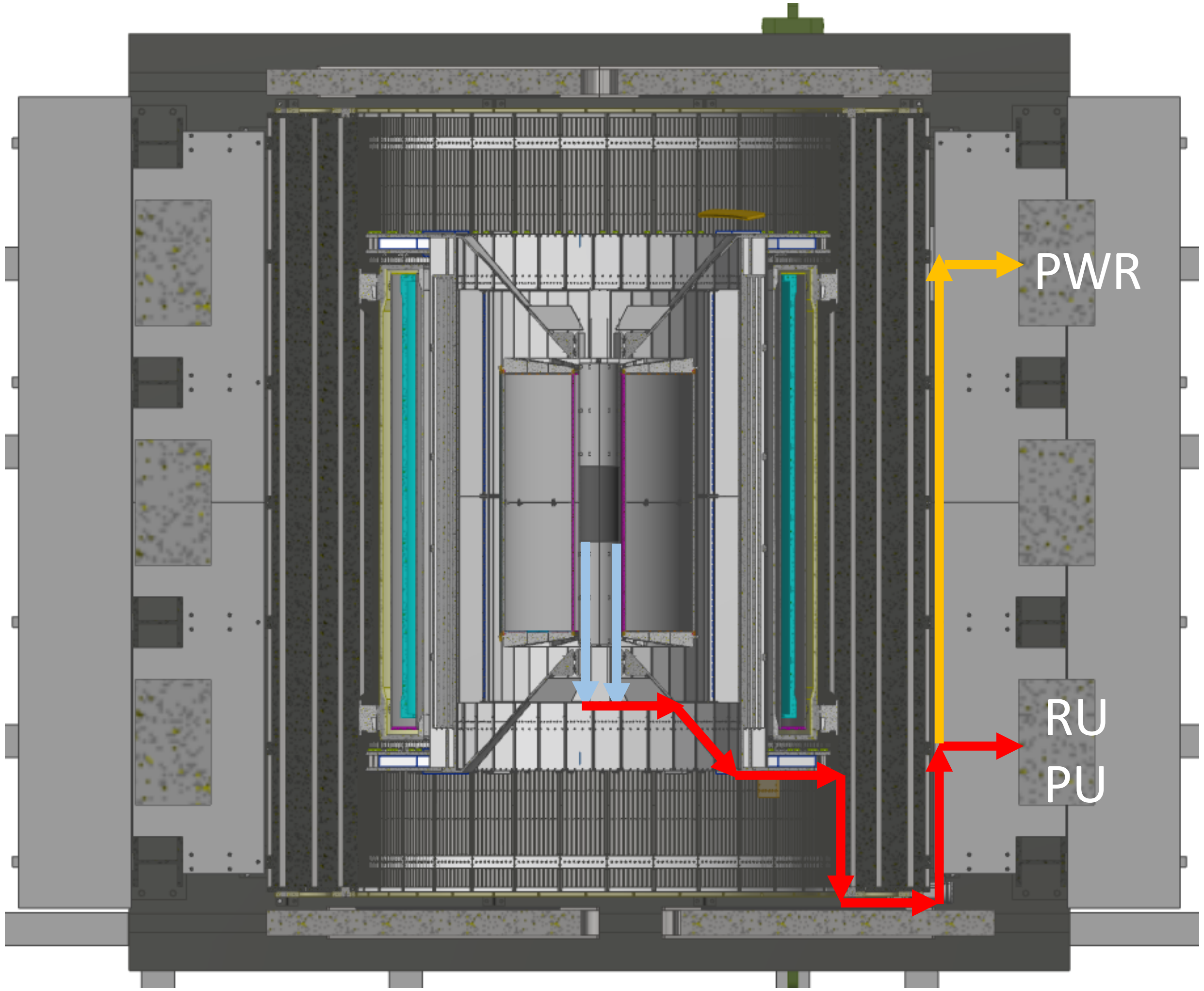


MVTX Services - Work in Progress

- Service racks located close to MVTX detector
  - Electronics, power etc
  - "Minimal cable length", 8m tested at CERN;
    - L~7.9m
    - R&D on 10m cables at LANL
- 48 RU and 24 PU
  - 1PU ->2RU
  - 6-U VME crates
- CAEN bulk power supply
  - located nearby
- Cooling plant
  - Location TBD



MVTX Readout and Power Cable Rout



BNL has approved "non-halogen free" cables for sPHENIX

ALICE ITS/IB final readout cables: ~8m

sPHENIX MVTX: 7.9+m

Cable-A: 1.4 m

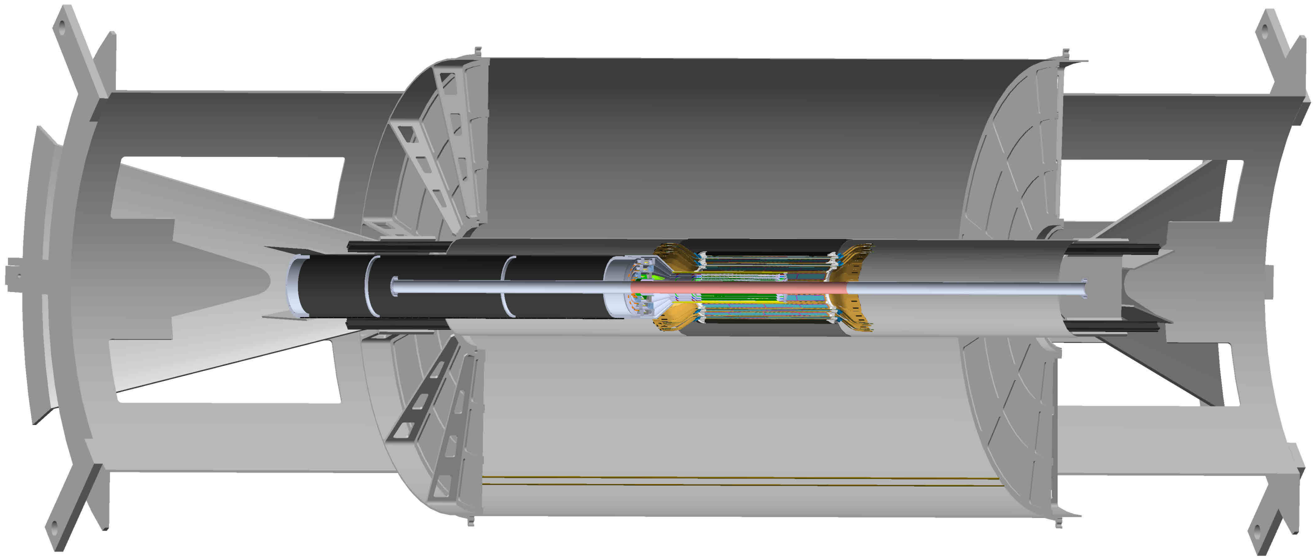
Cable-B: 6.5+ m

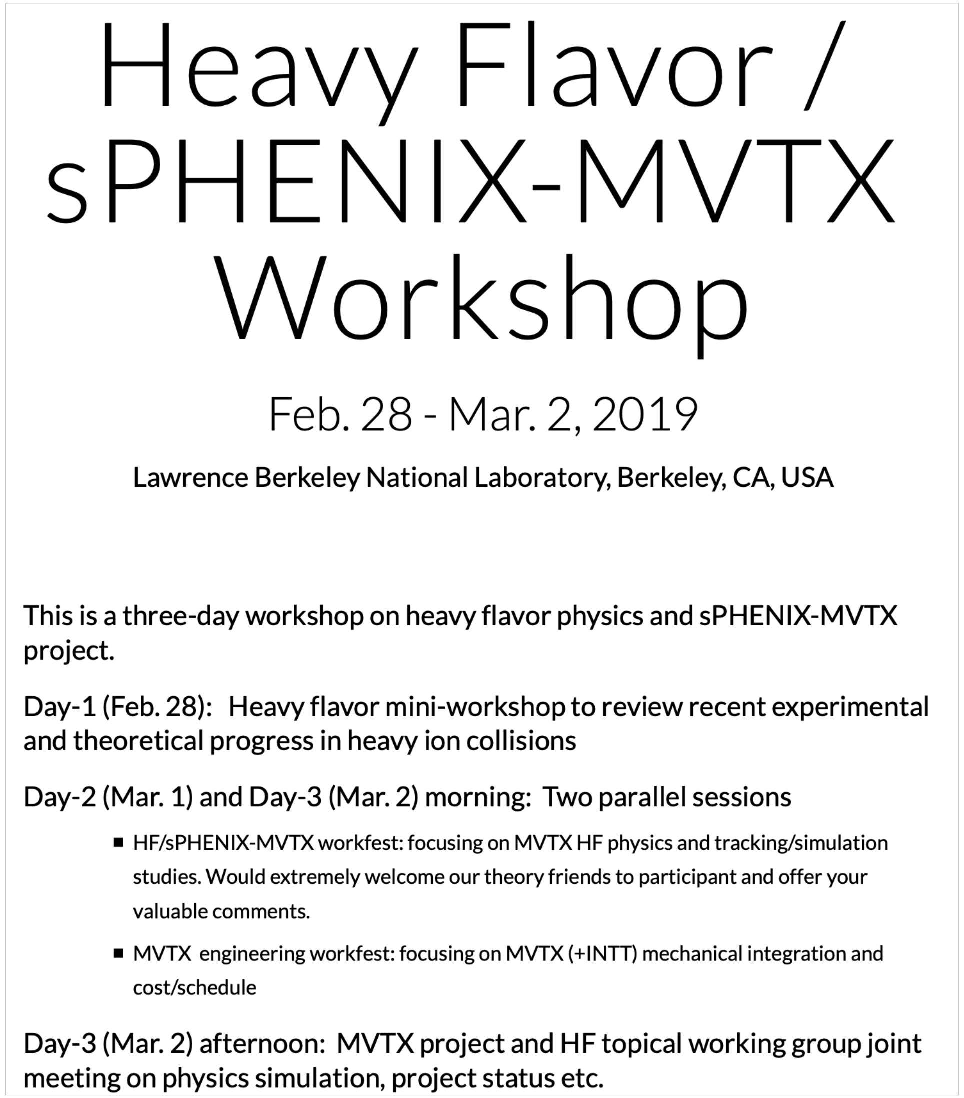
Power cable:4.7+ m

On-going R&D for ~10m

Major Topics for LBNL HF/MVTX Workshop 2/28-3/2, 2019

- New HF physics program development
- Total project Cost, $5M cap
- Cost of the mechanical system





Heavy Flavor / sPHENIX-MVTX Workshop

Feb. 28 - Mar. 2, 2019

Lawrence Berkeley National Laboratory, Berkeley, CA, USA

This is a three-day workshop on heavy flavor physics and sPHENIX-MVTX project.

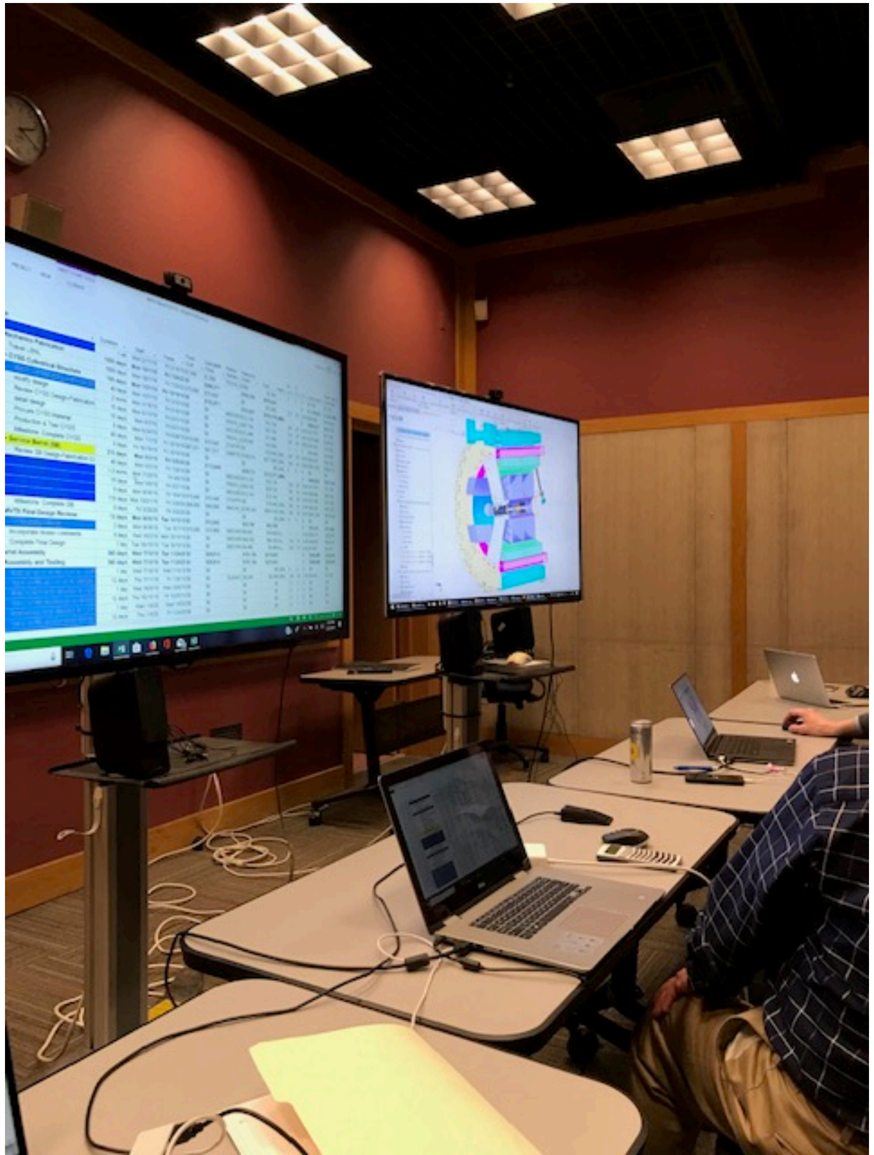
Day-1 (Feb. 28): Heavy flavor mini-workshop to review recent experimental and theoretical progress in heavy ion collisions

Day-2 (Mar. 1) and Day-3 (Mar. 2) morning: Two parallel sessions

- HF/sPHENIX-MVTX workfest: focusing on MVTX HF physics and tracking/simulation studies. Would extremely welcome our theory friends to participant and offer your valuable comments.
- MVTX engineering workfest: focusing on MVTX (+INTT) mechanical integration and cost/schedule

Day-3 (Mar. 2) afternoon: MVTX project and HF topical working group joint meeting on physics simulation, project status etc.

Mechanical System Discussions @LBNL

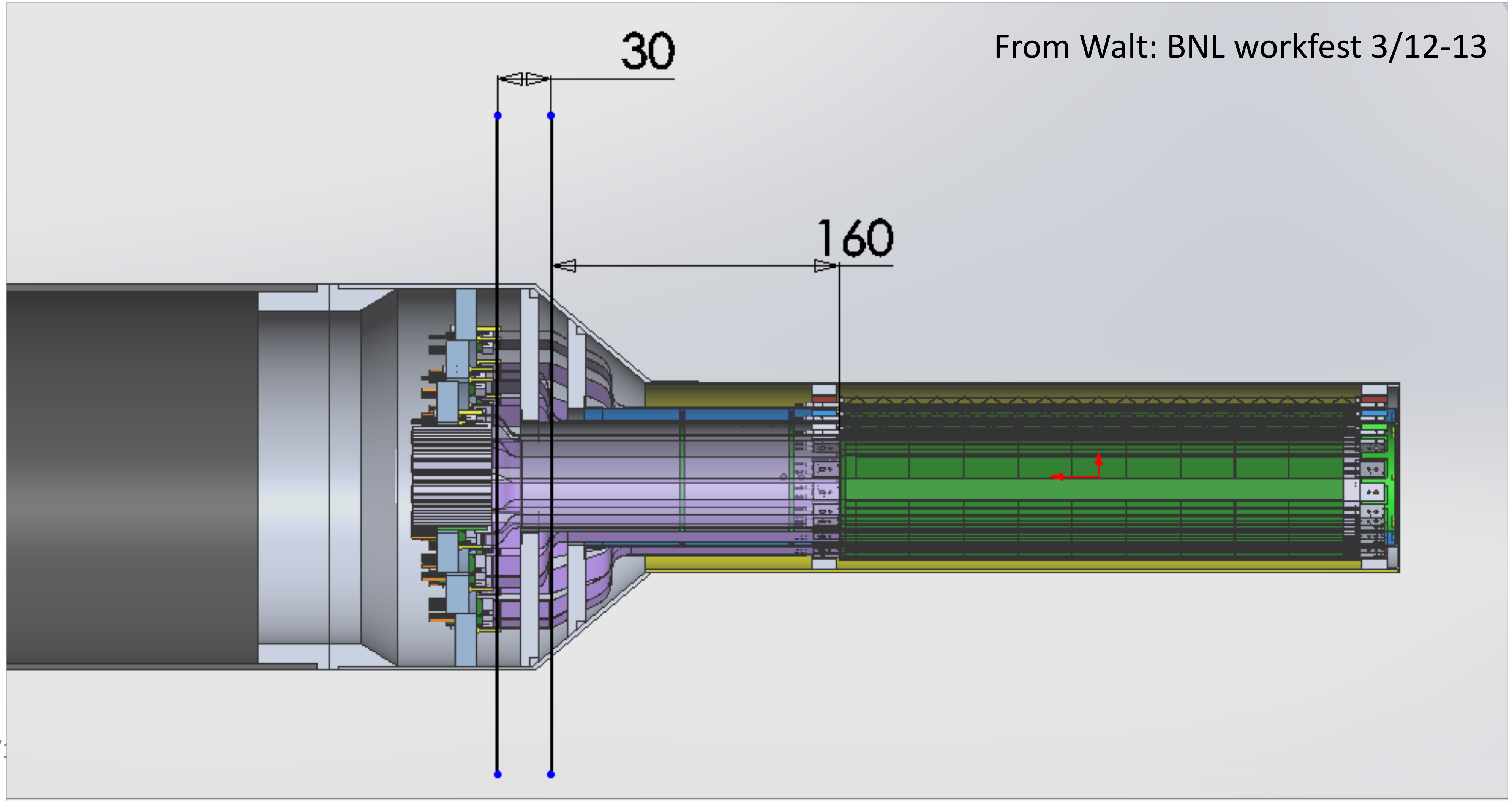


Discussed major carbon structures' design & production cost line by line, also production schedule @LBNL

Carbon Structures – Work in Progress

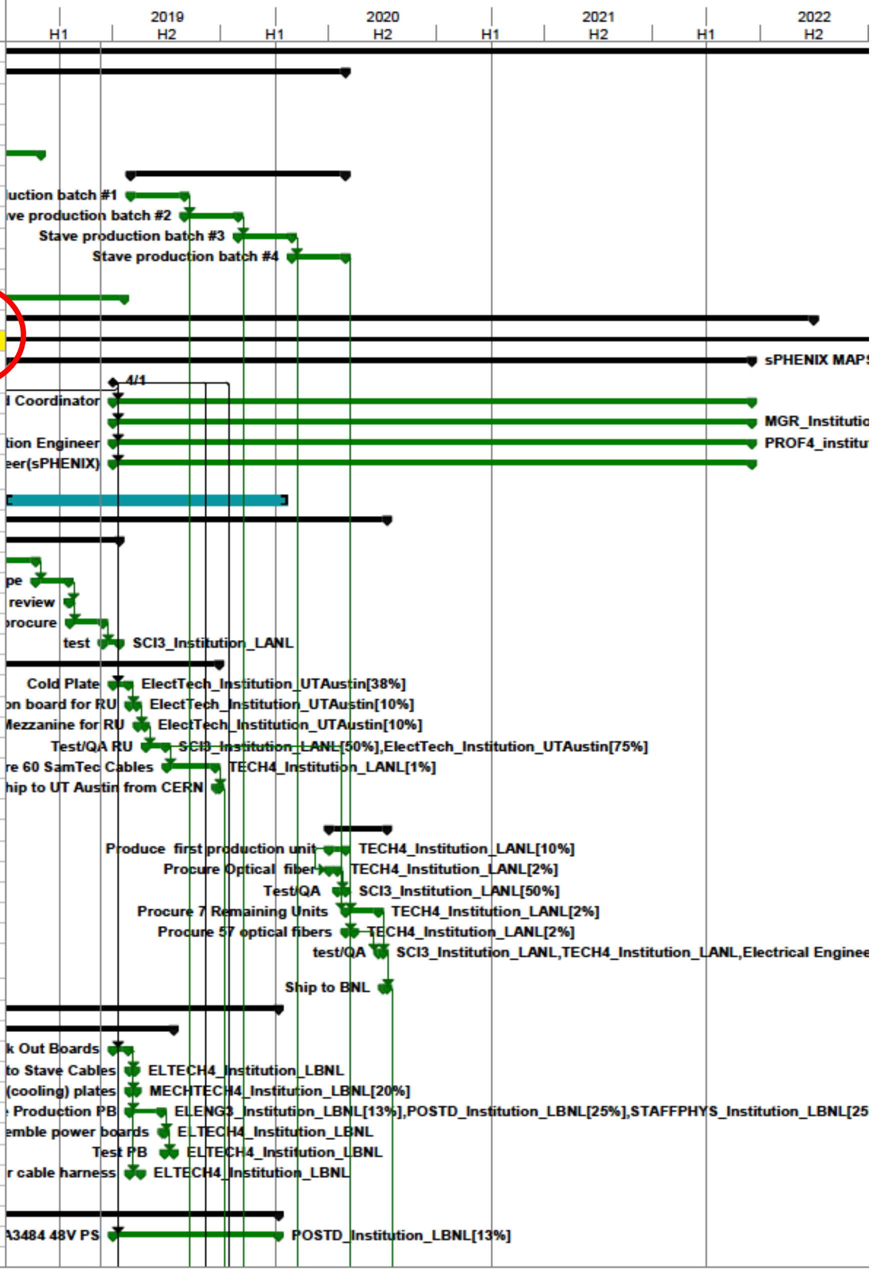
Ross' talk

- Conical sectors are expensive!
- A new design under development to avoid the conical structures



sPHENIX

ID	Task Mode	WBS	Task Name	Duration	Start	Finish	Fixed Cost	Calculated Fixed Cost	Resource Names	Resource Costs	Cost	Institut	Mat cont	Tota Con	Ove	cost+conting
1		1	**MVTX Inner Barrel**	**4492 days**	**Fri 10/21/05**	**Fri 1/27/23**	**$0**	**$1,206,230**		**$2,492,893**	**$3,699,123**				**0**	**$4,909,462**
2		**1.6**	**ALICE ITS Key Tasks**	**878 days**	**Mon 11/28/16**	**Tue 4/28/20**	**$0**	**$0**		**$0**	**$0**		**0**		**0**	**$0**
3		1.6.7	ALICE MAPS Production	240 days	Mon 11/28/16	Mon 11/6/17	$0	$0		$0	$0		0	0	0	$0
4		1.6.8	ALICE ITS IB FPC Production	200 days	Thu 6/1/17	Thu 3/22/18	$0	$0		$0	$0		0	0	0	$0
5		1.6.9	ALICE ITS IB Stave frame Production	240 days	Fri 7/28/17	Thu 7/12/18	$0	$0		$0	$0		0	0	0	$0
6		1.6.10	ALICE ITS IB Stave Assembly	300 days	Mon 9/25/17	Thu 11/29/18	$0	$0		$0	$0		0	0	0	$0
7		**1.6.13**	**MVTX stave production at CERN**	**260 days**	**Wed 5/1/19**	**Tue 4/28/20**	**$0**	**$0**		**$0**	**$0**	**CERN**			**0**	**$0**
8		1.6.13.10	Stave production batch #1	13 wks	Wed 5/1/19	Tue 7/30/19	$0	$0		$0	$0		0	0	0	$0
9		1.6.13.11	Stave production batch #2	13 wks	Wed 7/31/19	Tue 10/29/19	$0	$0		$0	$0		0	0	0	$0
10		1.6.13.12	Stave production batch #3	13 wks	Wed 10/30/19	Tue 1/28/20	$0	$0		$0	$0		0	0	0	$0
11		1.6.13.13	Stave production batch #4	13 wks	Wed 1/29/20	Tue 4/28/20	$0	$0		$0	$0		0	0	0	$0
12		1.6.11	ALICE ITS Electronics Pre-Production	100 days	Mon 1/1/18	Fri 5/18/18	$0	$0		$0	$0		0	0	0	$0
13		1.6.12	ALICE ITS Electronics Production	240 days	Mon 5/21/18	Fri 4/19/19	$0	$0		$0	$0		0	0	0	$0
14		**1.7**	**sPHENIX Milestones**	**1332 days**	**Mon 5/8/17**	**Fri 7/1/22**	**$0**	**$0**		**$0**	**$0**				**0**	**$0**
21		**1.5**	**MVTX Project**	**4492 days**	**Fri 10/21/05**	**Fri 1/27/23**	**$0**	**$1,206,230**		**$2,492,893**	**$3,699,123**				**0**	**$4,909,462**
22		**1.5.1**	**MVTX Project Management**	**904 days**	**Mon 10/1/18**	**Thu 3/17/22**	**$0**	**$50,000**		**$493,050**	**$5[illegible]50**	**LANL**			**0**	**$64[illegible]**
23		1.5.1.1	Milestone Start MVTX	0 days	Mon 4/1/19	Mon 4/1/19	$0	$0		$0	$0		0	0	0	$0
24		1.5.1.2	lead Coordinator	774 days	Mon 4/1/19	Thu 3/17/22	$0	$0		$0	$0		.2	.2	0	$0
25		1.5.1.3	Project Manager	774 days	Mon 4/1/19	Thu 3/17/22	$0	$0	MGR_Ins	$394,478	$394,478		.2	.2	0	$473,374
26		1.5.1.4	Mechanical Integration Engineer	774 days	Mon 4/1/19	Thu 3/17/22	$0	$0	PROF4_i	$98,572	$98,572		.2	.2	0	$118,286
27		1.5.1.5	Electronics Integration Engineer(sPHENIX)	774 days	Mon 4/1/19	Thu 3/17/22	$0	$0		$0	$0		.2	.2	0	$0
28		1.5.1.6	Travel	[illegible]42 days	Mon 10/1/18	Tue 1/21/20	$50,000	$50,000		$0	$50,000		0	0	0	$50,000
29		**1.5.2**	**Electronics**	**3824.33 days**	**Fri 10/21/05**	**Wed 7/8/20**	**$0**	**$298,544**		**$102,336**	**$400,880**	**LANL**			**0**	**$492,285**
30		**1.5.2.1**	**Stave Extension Cable**	**182 days**	**Wed 8/1/18**	**Thu 4/11/19**	**$0**	**$0**		**$0**	**$0**	**LANL**			**0**	**$0**
31		1.5.2.1.1	design	4 mons	Wed 8/1/18	Tue 11/20/18	$0	$0		$0	$0		.35	.35	0	$0
32		1.5.2.1.2	prototype	2 mons	Wed 11/21/18	Tue 1/15/19	$0	$0		$0	$0		.35	.35	0	$0
33		1.5.2.1.3	review	2 days	Wed 1/16/19	Thu 1/17/19	$0	$0		$0	$0		.35	.35	0	$0
34		1.5.2.1.4	procure	2 mons	Fri 1/18/19	Thu 3/14/19	$0	$0		$0	$0		.30	.30	0.09	$0
35		1.5.2.1.5	test	20 days	Fri 3/15/19	Thu 4/11/19	$0	$0	SCI3_Ins	$0	$0		.35	.35	0.09	$0
36		**1.5.2.2**	**RU**	**3622 days**	**Fri 10/21/05**	**Fri 9/27/19**	**$0**	**$66,005**		**$21,694**	**$87,699**				**0**	**$116,167**
37		1.5.2.2.2	Cold Plate	4 wks	Mon 4/1/19	Fri 4/26/19	$12,104	$12,104	ElectTech	$5,472	$17,576		.35	.35	0.09	$23,728
38		1.5.2.2.8	Transition board for RU	2 wks	Mon 4/29/19	Fri 5/10/19	$8,716	$8,716	ElectTech	$720	$9,436		.2	.2	0	$11,323
39		1.5.2.2.9	Power Mezzanine for RU	2 wks	Mon 5/13/19	Fri 5/24/19	$4,685	$4,685	ElectTech	$720	$5,405		.2	.2	0	$6,486
40		1.5.2.2.3	Test/QA RU	1.25 mons	Mon 5/27/19	Fri 6/28/19	$7,500	$7,500	SCI3_Ins	$13,500	$21,000		.35	.35	0.09	$28,350
41		1.5.2.2.5	Procure 60 SamTec Cables	60 days	Mon 7/1/19	Fri 9/20/19	$30,000	$30,000	TECH4_I	$922	$30,922	LANL	.35	.35	0.09	$41,745
42		1.5.2.2.7	Ship to UT Austin from CERN	1 wk	Mon 9/23/19	Fri 9/27/19	$2,000	$2,000		$0	$2,000		.35	.35	0.09	$2,700
43		1.5.2.2.10	Ship to BNL	5 days	Fri 10/21/05	Thu 10/27/05	$1,000	$1,000	ElectTech	$360	$1,360		.35	.35	0	$1,836
44		**1.5.2.3**	**FELIX**	**70.33 days**	**Wed 4/1/20**	**Wed 7/8/20**	**$0**	**$76,400**		**$20,275**	**$96,675**				**0**	**$116,310**
45		1.5.2.3.1	Produce first production unit	4 wks	Wed 4/1/20	Tue 4/28/20	$8,000	$8,000	TECH4_I	$3,152	$11,152		.2	.2	0.12	$13,382
46		1.5.2.3.2	Procure Optical fiber	2 wks	Wed 4/1/20	Tue 4/14/20	$50	$50	TECH4_I	$315	$365		.2	.2	0.09	$438
47		1.5.2.3.3	Test/QA	2 wks	Wed 4/15/20	Tue 4/28/20	$0	$0	SCI3_Ins	$0	$0		.2	.2	0.09	$0
48		1.5.2.3.4	Procure 7 Remaining Units	8 wks	Wed 4/29/20	Tue 6/23/20	$56,000	$56,000	TECH4_I	$1,261	$57,261	LANL	.2	.2	0.09	$68,713
49		1.5.2.3.5	Procure 57 optical fibers	2 wks	Wed 4/29/20	Tue 5/12/20	$2,850	$2,850	TECH4_I	$315	$3,165		.2	.2	0.12	$3,798
50		1.5.2.3.6	test/QA	5.33 days	Wed 6/24/20	Wed 7/1/20	$7,500	$7,500	SCI3_Ins Engineer	$15,232	$22,732		.2	.2	0.09	$27,278
51		1.5.2.3.7	Ship to BNL	1 wk	Wed 7/1/20	Wed 7/8/20	$2,000	$2,000		$0	$2,000		.35	.35	0.12	$2,700
52		**1.5.2.4**	**MAPS Power System**	**3692.77 days**	**Fri 10/21/05**	**Mon 1/6/20**	**$0**	**$156,139**		**$60,367**	**$216,506**	**LBNL**			**0**	**$259,807**
53		**1.5.2.4.1**	**Power Boards**	**3567 days**	**Fri 10/21/05**	**Fri 7/12/19**	**$0**	**$79,020**		**$49,672**	**$128,692**	**LBNL**			**0**	**$154,431**
54		1.5.2.4.1.7	Fabricate Break Out Boards	20 days	Mon 4/1/19	Fri 4/26/19	$6,600	$6,600		$0	$6,600		.2	.2	0.09	$7,920
55		1.5.2.4.1.8	Fabricate PB to Stave Cables	[illegible]0 hrs	Mon 4/29/19	Wed 5/8/19	$8,000	$8,000	ELTECH	$7,080	$15,080		.2	.2	0.09	$18,096
56		1.5.2.4.1.10	Fabricate cold (cooling) plates	2 wks	Mon 4/29/19	Fri 5/10/19	$3,420	$3,420	MECHTE	$2,112	$5,532		.2	.2	0	$6,638
57		1.5.2.4.1.9	Fabricate Production PB	40 days	Mon 4/29/19	Fri 6/21/19	$60,000	$60,000	ELENG3	$8,620	$68,620		.2	.2	0.09	$82,345
58		1.5.2.4.1.11	Assemble power boards	30 hrs	Mon 6/24/19	Thu 6/27/19	$0	$0	ELTECH	$3,540	$3,540		.2	.2	0	$4,248
59		1.5.2.4.1.12	Test PB	90 hrs	Thu 6/27/19	Fri 7/12/19	$0	$0	ELTECH	$10,620	$10,620		.2	.2	0	$12,744
60		1.5.2.4.1.13	Power cable harness	15 days	Mon 4/29/19	Fri 5/17/19	$0	$0	ELTECH	$14,160	$14,160		.2	.2	0	$16,992
61		1.5.2.4.1.14	Ship to BNL	[illegible]0 hrs	Fri 10/21/05	Wed 10/26/05	$1,000	$1,000	ELTECH	$3,540	$4,540		.2	.2	0	$5,448
62		**1.5.2.4.2**	**Power Supplies**	**3692.77 days**	**Fri 10/21/05**	**Mon 1/6/20**	**$0**	**$77,119**		**$10,695**	**$87,814**				**0**	**$105,377**
63		1.5.2.4.2.1	CAEN A3484 48V PS	20[illegible].77 days	Mon 4/1/19	Mon 1/6/20	$8,607	$8,607	POSTD_I	$0	$8,607		.2	.2	0.09	$10,328
64		1.5.2.4.2.2	CAEN SY4527 Main Frame	30 days	Fri 10/21/05	Thu 12/1/05	$11,620	$11,620		$0	$11,620		.2	.2	0.09	$13,944



Latest Budget Update

- The cost is $3,699K, and if we add BNL's global contingency of 30%, the project total cost would be $3.7M x 1.3 = $4.81M

- If we go with the detailed contingencies discussed at LBNL (some less but some are higher than 30%), the total project cost is $4.91M

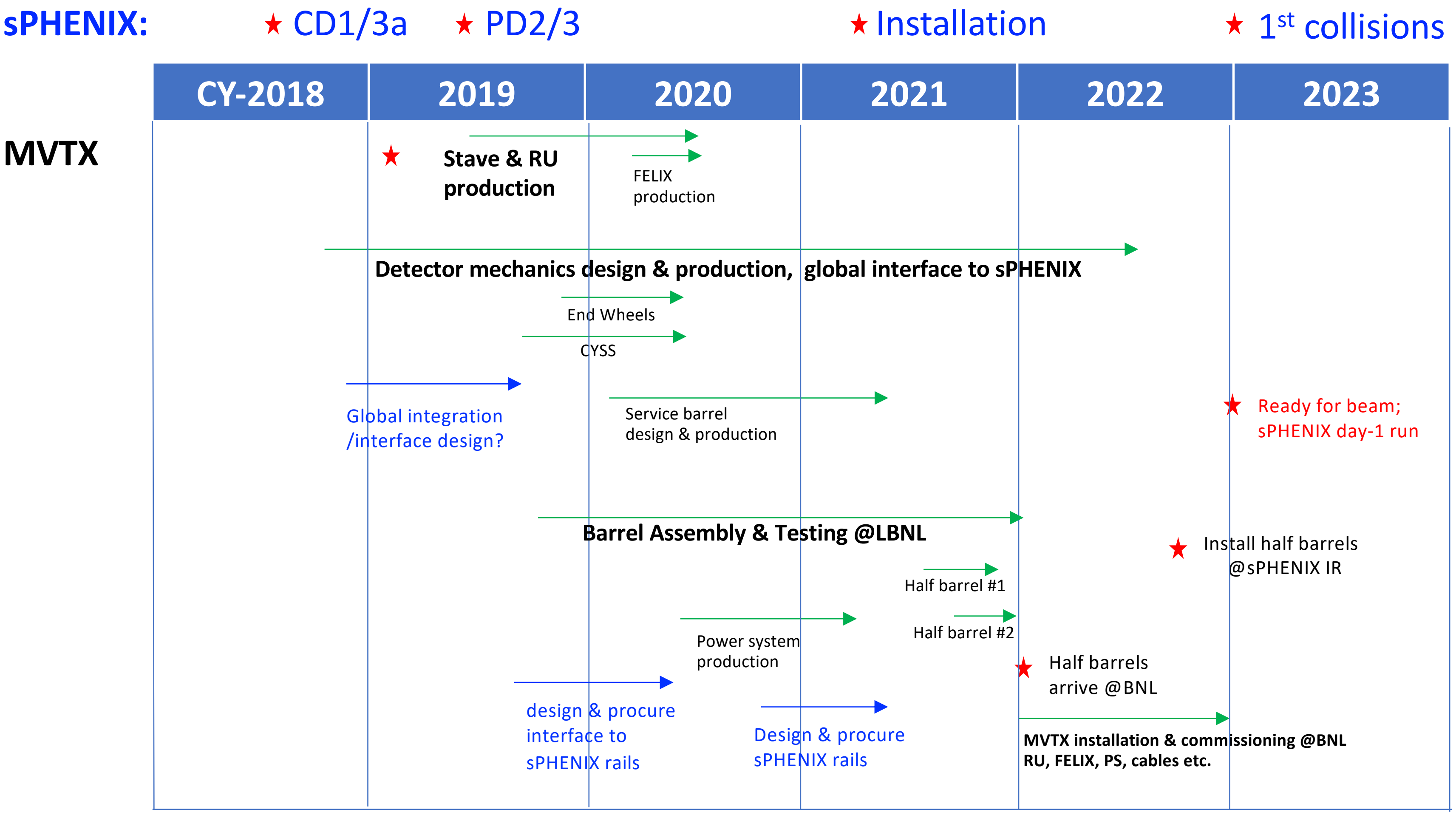
- Moved the Electrical Integration Project management (~$100K) and Commissioning effort (~$155K) from MVTX to sPHENIX

Double checking all the numbers and update the budget in the P6 SOON

MVTX Production Schedule Update

- Stave production @CERN
  - May 2019- May 2020, 84 staves
  - 4-stave/week
- Stave acceptance test @LBNL
  - MOSAIC system, 9/2019 – 5/2020
- Final mechanical design work
  - May 2019 – $$ available soon(?)
  - CYSS, End wheels
  - Service barrel and interface
- MVTX detector assembly at LBNL
  - LBNL ALICE ML stave production ends ~12/2019, a total of 60 ML staves
  - Start MVTX detector assembly ~ late summer of 2019 (or after the completion of ALICE ML?)
- MVTX full half-barrel detector test @LBNL
  - Starts ~mid of 2021
  - Using full readout system if ready: 24RU + 12PU + 3FELIX/2 servers

MVTX Schedules and Milestones, in progress (3/2019)



Upcoming BNL Director's Review "Breakout Session 4" – Silicon Upgrade

- April 9-11 Reviews@BNL

The review panel is requested to answer the following questions for the sPHENIX Tracking System Upgrades:

1. Conceptual Design: Is the conceptual design sound and likely to meet the project's technical performance requirements most efficiently and effectively?
2. Project Scope: Are the project's scope and specifications sufficiently defined to support the preliminary cost and schedule estimates? Are the interfaces with the sPHENIX MIE project and the Infrastructure and Facility Upgrade Project properly understood and documented?
3. Risks: Are the project risks properly identified and appropriate mitigation strategies in place?
4. Cost and Schedule: Are the cost and schedule estimates credible and realistic for this stage of the project? Do they include adequate scope, cost, and schedule contingency?
5. Management: Is the project being properly managed at this stage? Is the documentation appropriate at this stage of the project?
6. ES&H: Is ES&H being properly addressed given the project's current stage of development?

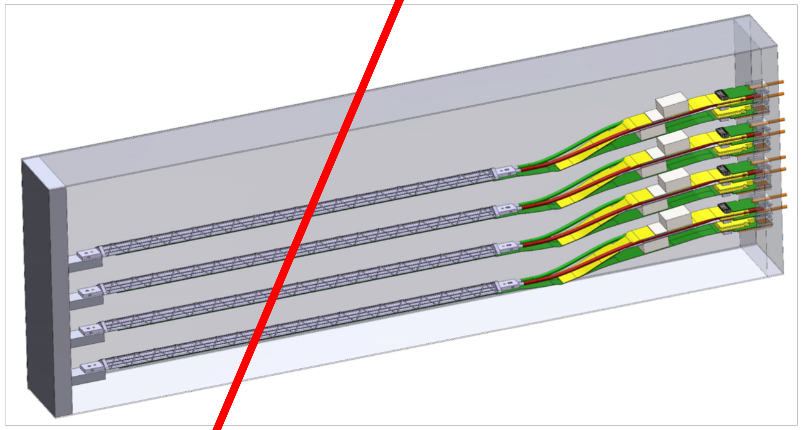
Wednesday, April 10, 2019 – Breakout Session 4 – Silicon Detectors*

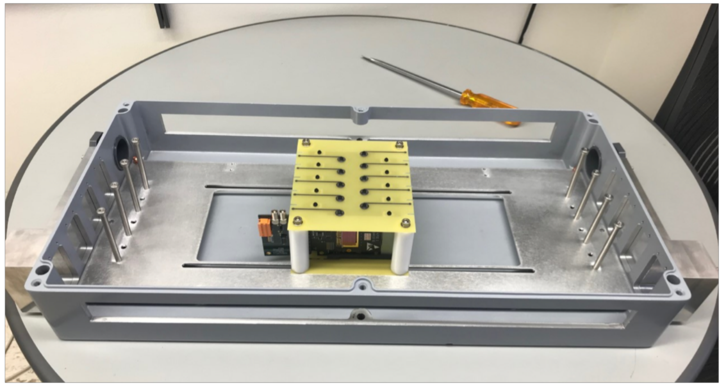
8:30 am	MVTX Overview/Management(20+10)
9:00 am	MVTX Sensors/Staves/Det Assembly(20+10)
9:30 am	MVTX Electronics(20+10)
10:00 am	MVTX Mechanics, Integration & Infrastructure(20+10)
10:30 am	Break(15)
10:45 am	MVTX Cost and Schedule(20+10)
11:15 am	INTT Overview/Management(20+10)
11:45 am	INTT Sensors/Staves/Det Assembly(20+10
12:15 am	Lunch(60)
1:15 pm	INTT Electronics(20+10)
1:45 pm	INTT Mechanics, Integration & Infrastructure(20+10)
2:15 pm	INTT Cost and Schedule(20+10)
2:45 pm	Committee Executive Session

We will present the latest updates at the review - ready for the final design and full production

Detector R&D in Progress

4-stave Telescope



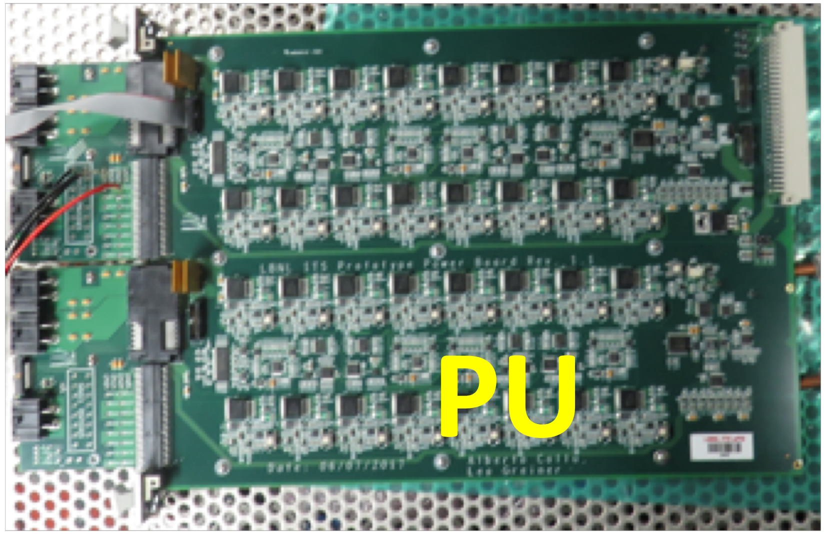


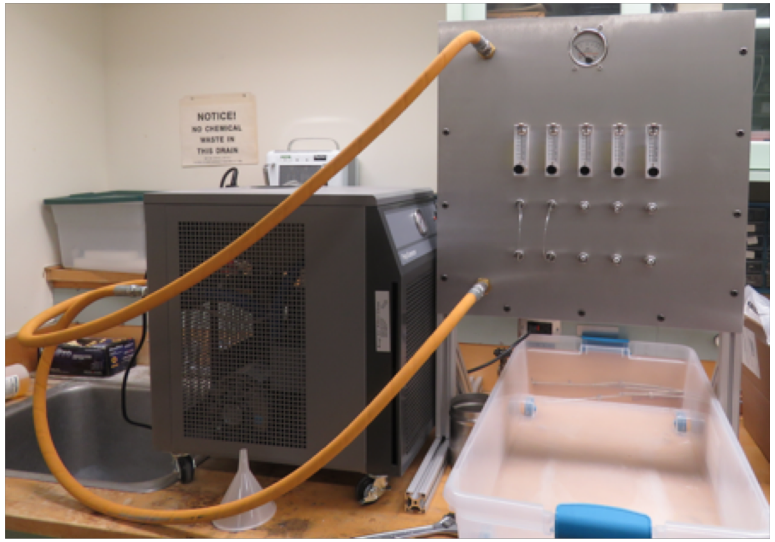
- MVTX prototype telescope beam test at Fermilab
  - Staves with “final” electronics and cables
  - Test beam planned for May, with sPHENIX INTT
- SamTec cables
  - AWG30(MVTX) vs AWG32(ITS),
    ~10m cables
- ALPIDE sensor characterization and optimization
  - Readout and trigger optimization for sPHENIX
  - Laser system setup in preparation

2019 Test Beam: 4-stave Telescope

From Sho

- Scheduled for May 22-28, @Fermilab
- Additions compared to the 2018 test beam:
  - Staves (from single chips)
  - Full-length MVTX signal cables (from 5 m off-the-shelf cables)
  - FELIX v2.0 (from v1.5)
  - Cooling system
  - Power board
  - sPHENIX GTM





Readout Electronics

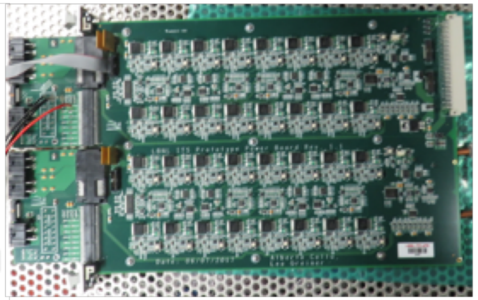
From Sho

- RU v2.1, Power Board in production by ALICE
- FELIX v2.0 in production by ATLAS
- MVTX firmware and software in sync with current ALICE and ATLAS work, with MVTX-specific logic developed under this LDRD

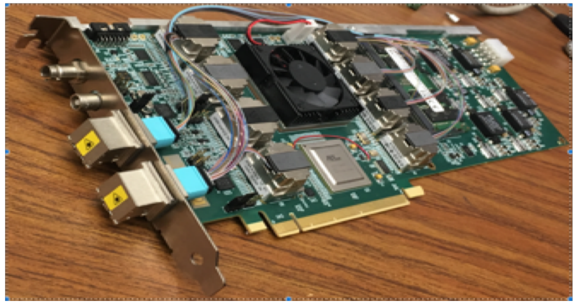
Key readout boards qualified and in production

RU v1.0

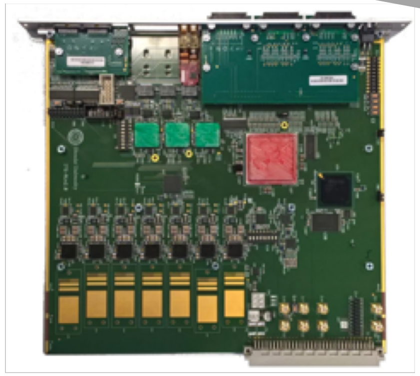
Prototype PB



FELIX v1.5



same functionality
production-qualified



RU v2.1

@LANL ~May

Production PB

in discussion with LBNL

FELIX v2.0

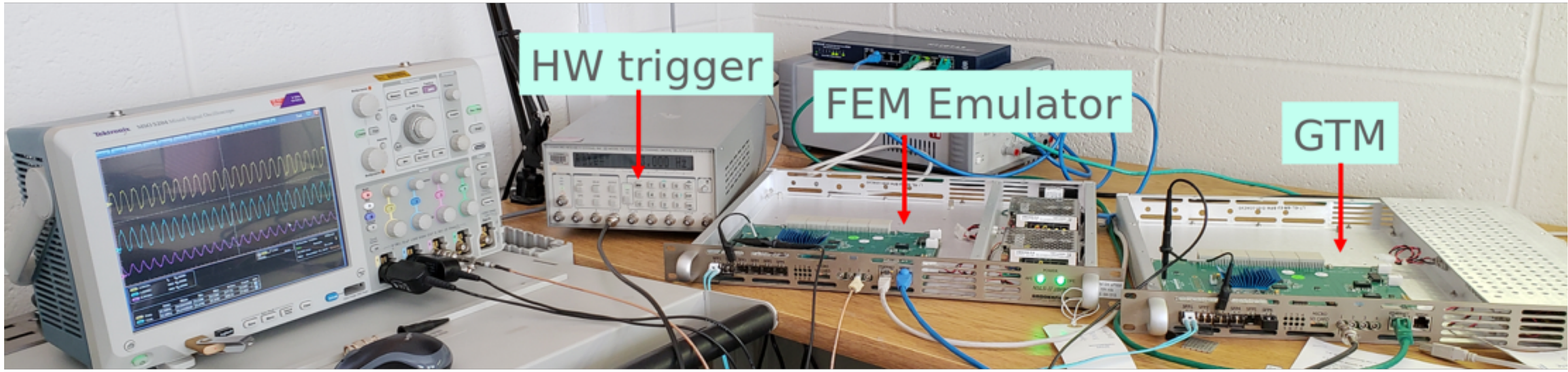
in hand @LANL

sPHENIX DAQ integration

From Sho

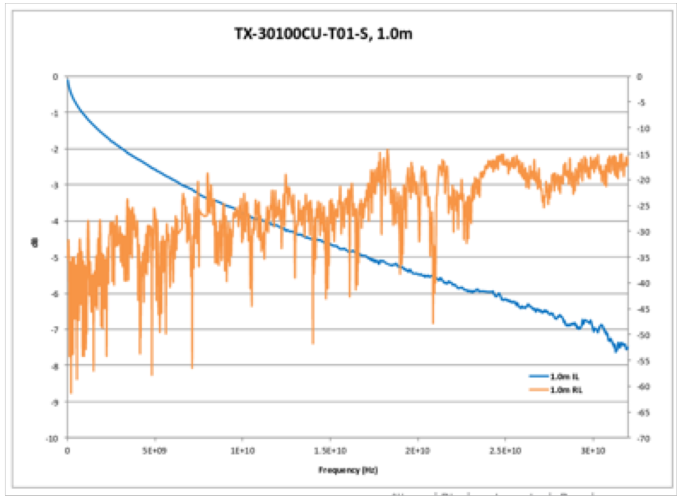
- sPHENIX detectors implement “plugins” to tie in to the central DAQ; the MVTX plugin was demonstrated at the 2018 test beam
- sPHENIX clock and trigger is distributed by Granule Timing Module (GTM): one BNL prototype at LANL
    - We have implemented the “receiver” in FELIX that allows MVTX to receive a trigger from sPHENIX;
- MVTX is participating in discussions for the sPHENIX DAQ design

MVTX is fully integrated with sPHENIX

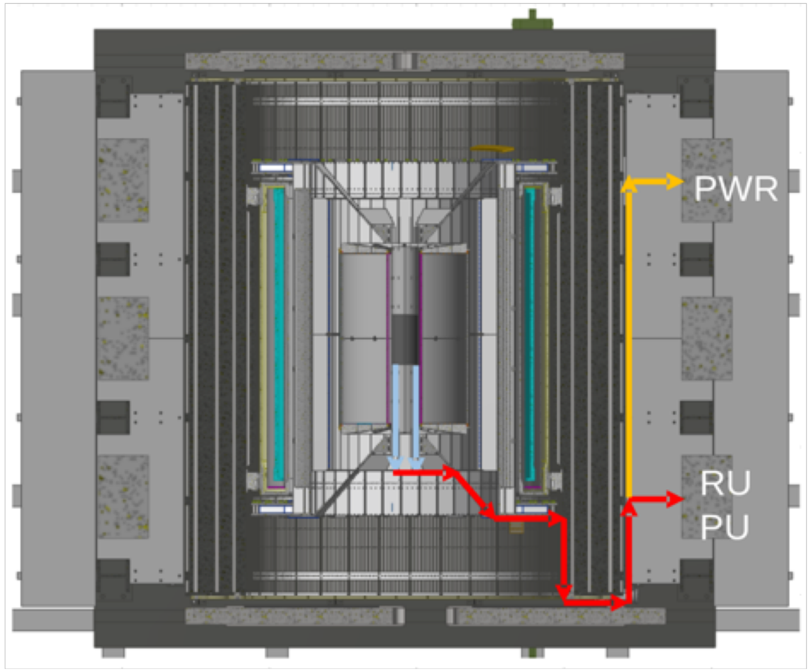


Readout Cable Testing

From Sho



- BNL has approved non-halogen-free cables (30 AWG, FEP dielectric); improved signal integrity
- sPHENIX cable run estimates are converging: 1.4 + 6.5 m
- Ordered SamTec cables for 1.2/2.65 + 5.3/8.8 m (total length 6.5 - 11.45 m)
- We will qualify these cables using stave and RU (bit error rates, statistical eye), and scope/network analyzer



We will test full-length MVTX cables in the next months

Summary of Near Term Tasks & Schedule

- RU production through ALICE: 60 RUs
  - 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
- Stave production through ALICE: 84 staves (ALICE Gold/Silver QA)
  - sPHENIX sensor production ~April 2019
    - Stave assembly starts @CERN, ~ April 2019, ~12 months to finish
  - Acceptance test and QA at LBNL, ~late 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: starting ~ late summer 2019
  - To setup assembly & test lab as soon as fund available
- Safety, slow-control and monitoring in progress - Mike's talk
- MVTX detector commissioning at BNL: ~summer 2021
  - Setup lab, pre-installation commissioning
  - IR installation
- (Physics & detector simulations, tracking improvement etc., work in progress) – Jin's talk

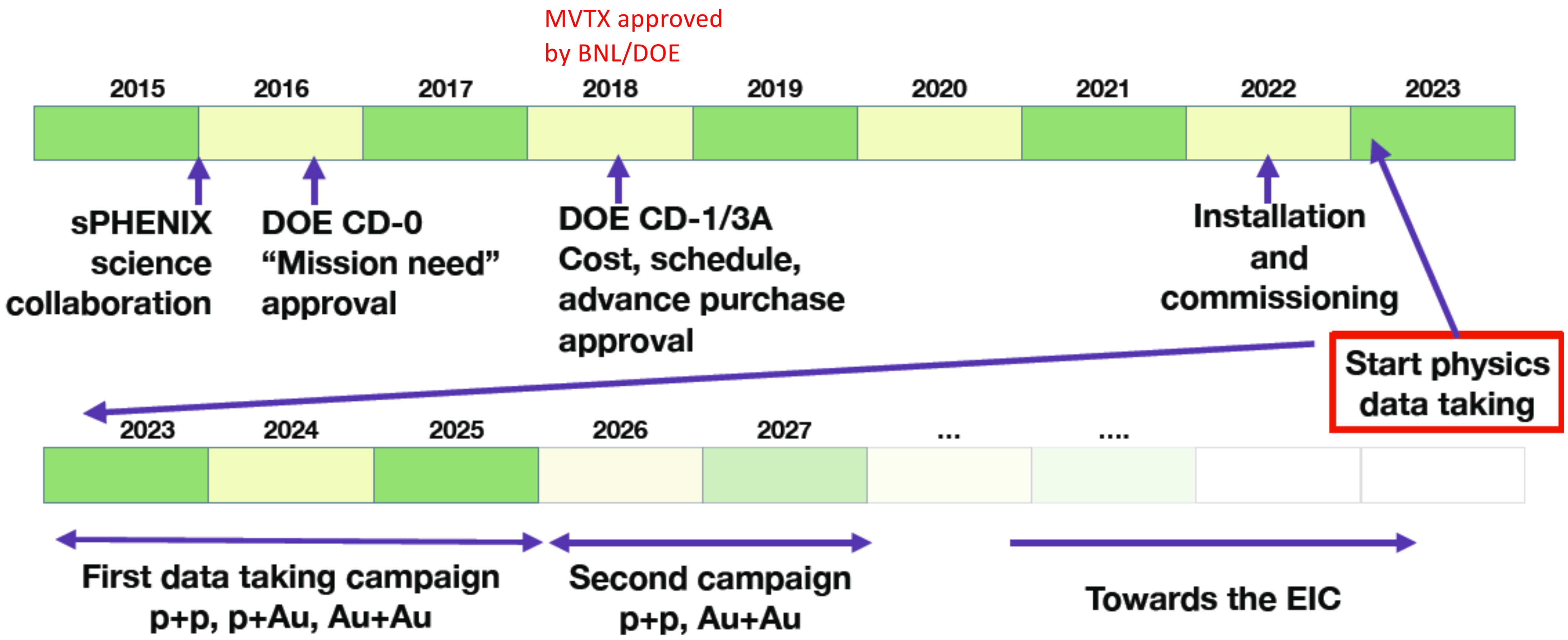
Great opportunity for university groups to join the effort & contribute!

- QA & Test
- Detector assembly
- Control & monitoring
- Simulations and analysis

Summary: MVTX - WBS 3.2

- MS Project being updated, now in the sPHENIX P6
  - Latest Cost & Schedule under review, under $5M cap
- Stave and RU production through US-ALICE
  - 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 ~ April 2019
- MVTX detector design & construction
  - About $5M to be added to the sPHENIX Management Portfolio
    - As a separated project from the MIE
      - Mechanical system design and fabrication
      - Update baseline cost and schedule soon
      - Monthly report to sPHENIX and BNL upper management
    - Will NOT be part of CD-2/3 DOE review
    - Engineering design work in progress, MIT/LANL et al
    - Construction and assembly work in late summer 2019
  - **Open MVTX accounts in progress, for full production**

sPHENIX Status and Plan

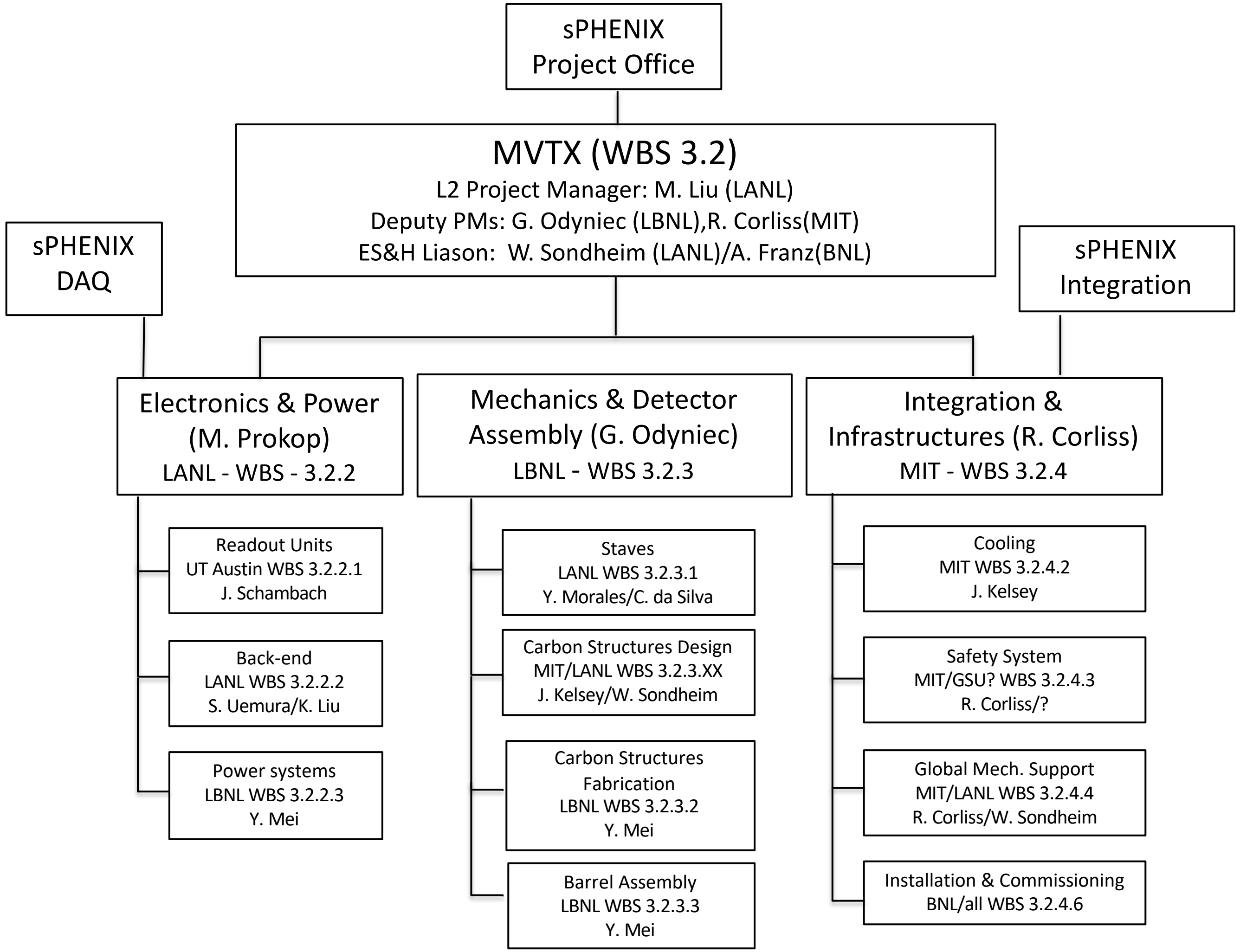


Thank You!

backup

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.

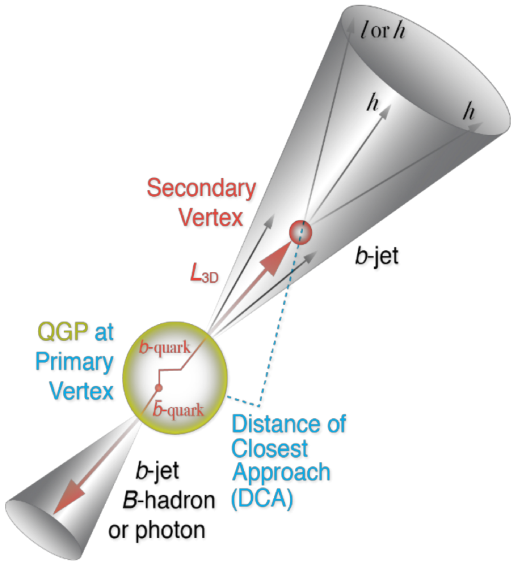
Sun Yat-Sen University (SYSU/China) : MVTX detector and physics simulations.

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

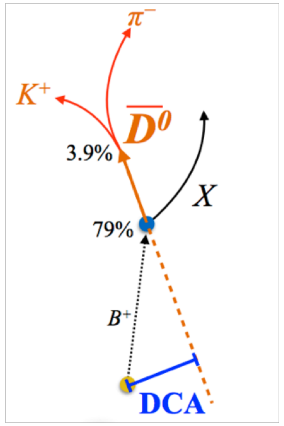
Yonsei University (YSU/Korea) : MAPS chip production QA, readout electronics test and simulations

Open Charm & Beauty Production

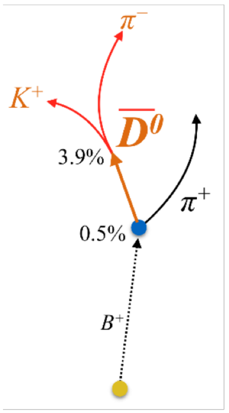
Hadron	Abundance	$c\tau$ (μm)
D^0	61%	123
D^+	24%	312
D_s	8%	150
Λ_c	6%	60
B^+	40%	491
B^0	40%	455
B_s	10%	453
Λ_b	10%	435



$B \to \overline{D}^0 + X$



$B^+ \to \overline{D}^0 \pi^+$



b-tagged jet and cor.	p_T>15 GeV

$B \to \overline{D}^0 + X$ 60%

$B^+ \to \overline{D}^0 \pi^+$ 0.5%

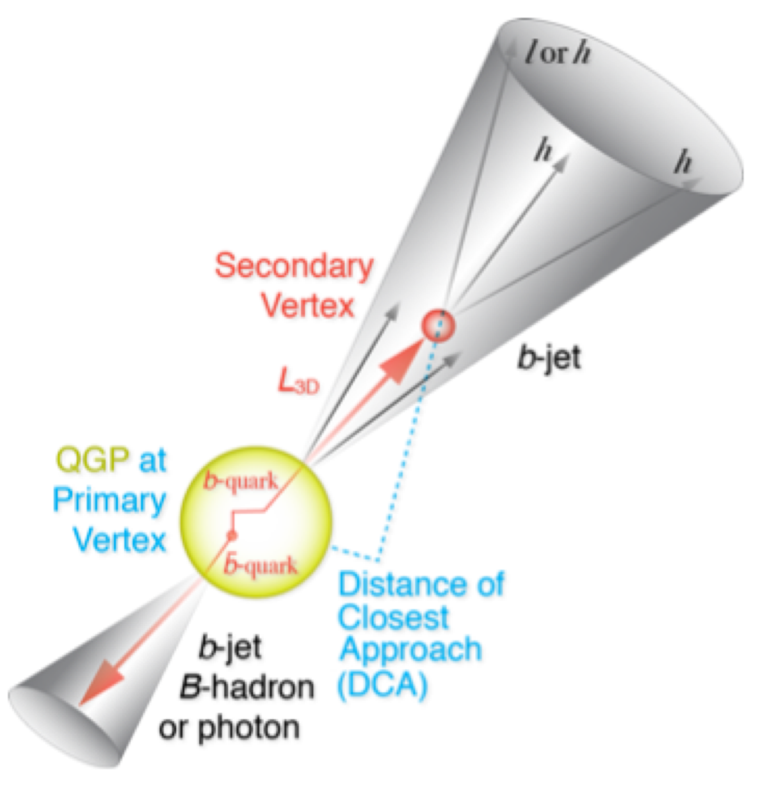
p_T<15 GeV

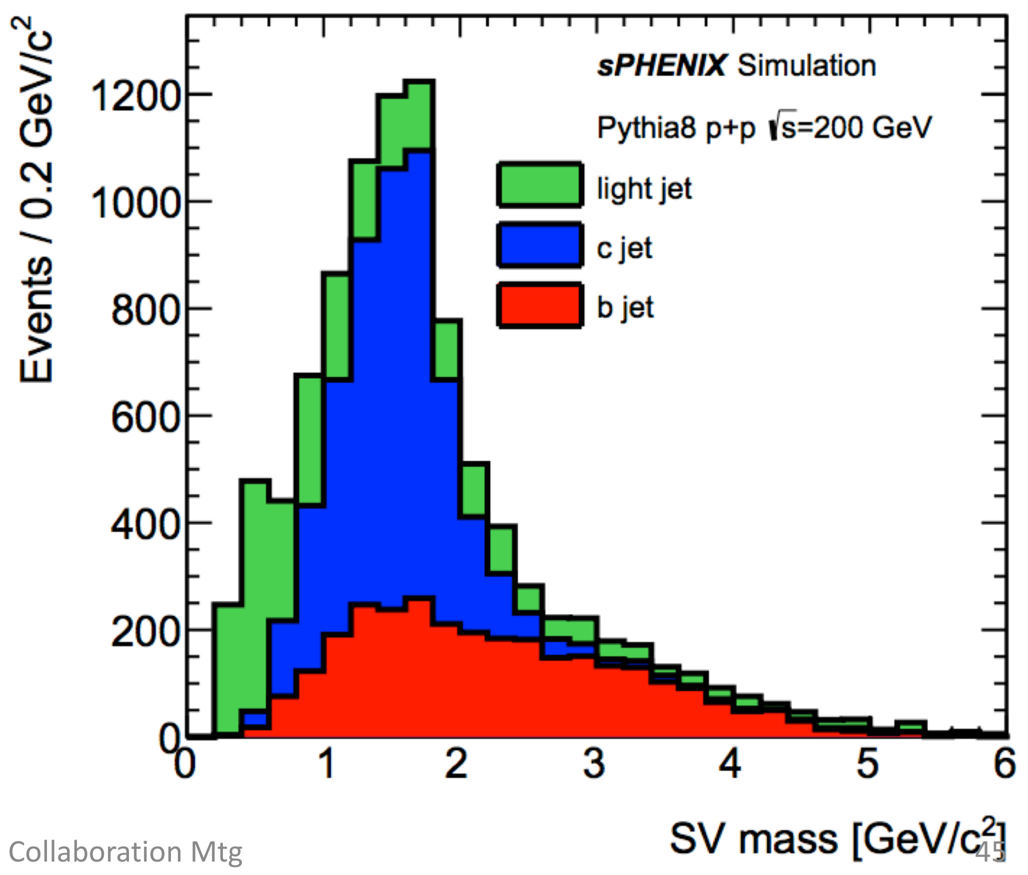
Exploring $B \to J/\psi + X$ and more

B-Hadron & b-Jet Tagging

Jin, Tony, Sanghoon

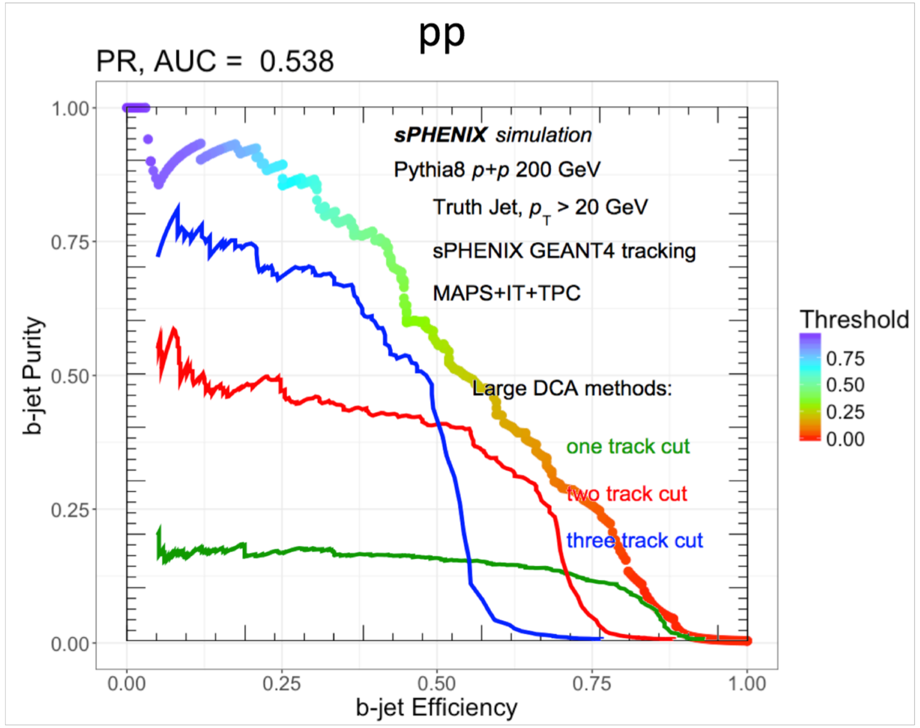
- Detected using the long lifetime of bottom quark hadrons:
  - Displaced tracks
  - Large 2nd vertex invariant mass
- Need high precision tracking and vertex determination – **MVTX!**
- Need excellent jet detection capabilities – **sPHENIX!**

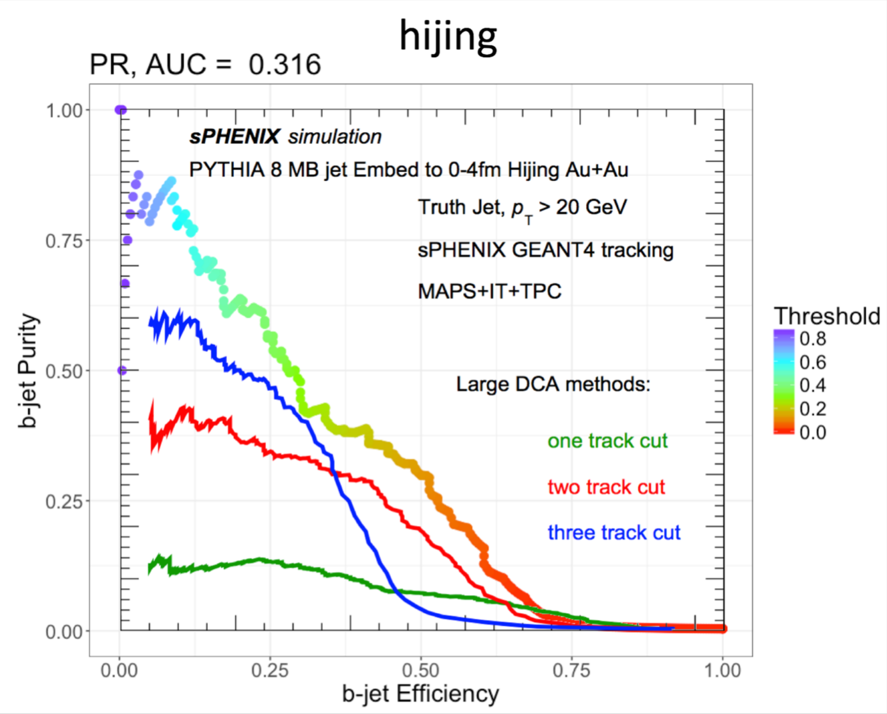




Tony's talk

Expected Performance





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 = 6×10^{12} N_{eq}/cm^2

Outer layers:

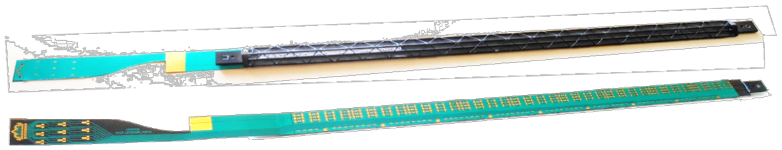
L1 = 0.6 x L0; L2 = 0.4 x L0

Sensors tested to full MVTX NIEL and ~3x TID @ALICE (as of 9/18/2018)

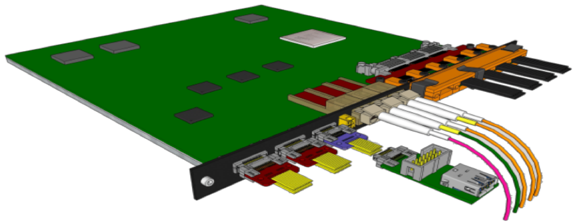
MVTX Sensors and Electronics Production

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

Design & Production Plan

Detector Assembly and Integration

LBNL Scope

- Stave reception from CERN and testing
- Power system
- Carbon composite structure production
- Half-barrel assembly and testing

MIT/Bates Responsibilities

- Cooling System (1.5.4.2)
  - Modify ALICE design
  - Safety system
- Mechanical model (1.5.3.2.1.1)
  - Inner support structures (1.5.3.2.2.1, 1.5.3.2.3.2?)
  - Service barrel (1.5.3.2.3.3?)
  - Interface to sPHENIX exterior (1.5.3.2.1.1?)
  - Installation procedure (1.5.3.2.1.1?)

2018 Dec 5 MVTX Workfest, FSU 2

Detailed sharing of engineering design, FEA/simulations, review and fabrication discussed
Engineering resources at LANL/MIT/LBNL

Stave and RU Production QA Plan Documents Available

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

Staves

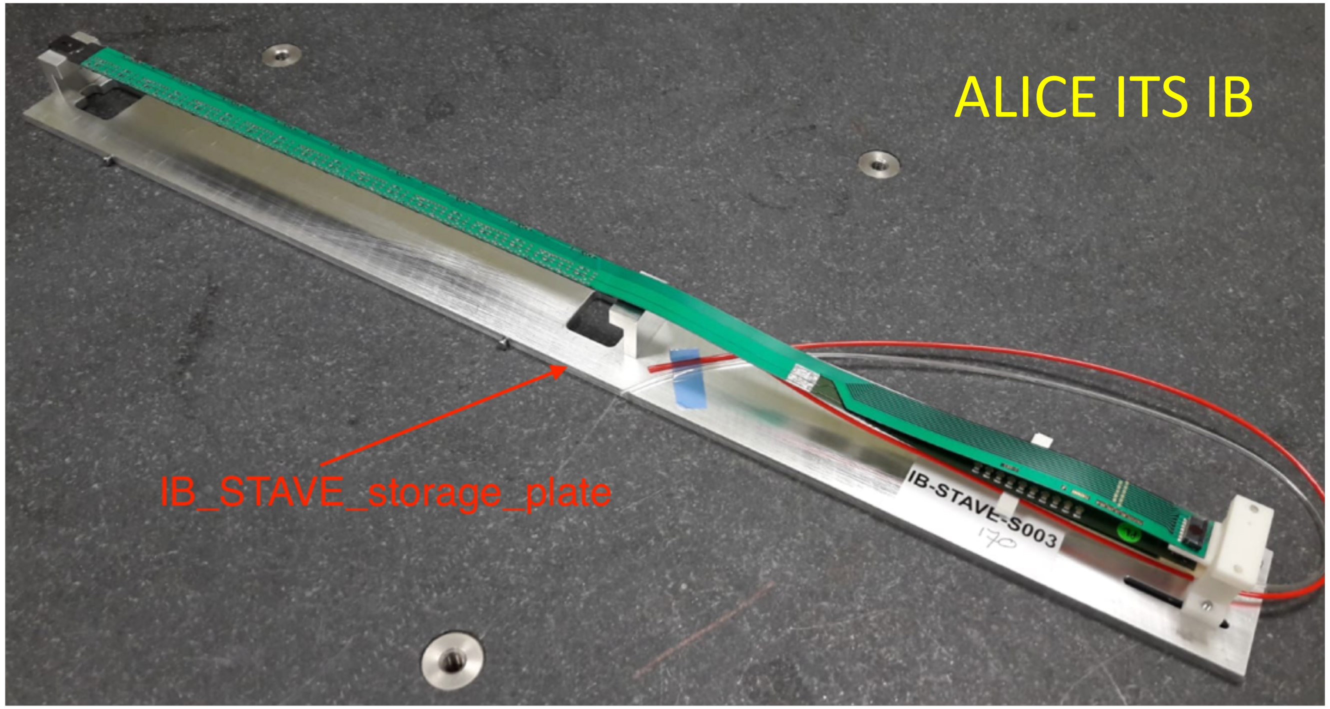
- Purchase 84 staves from ALICE/CERN
  - 48 + 28(spares for 2 inner layers) + 8 spares
  - Production following the completion of ALICE ITS/IB
  - Starting ~Oct. 2018, will last 6-12 months
  - Fully tested at CERN before shipping to US
    - All Gold/Silver staves (same as ALICE IB)
    - A LANL postdoc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

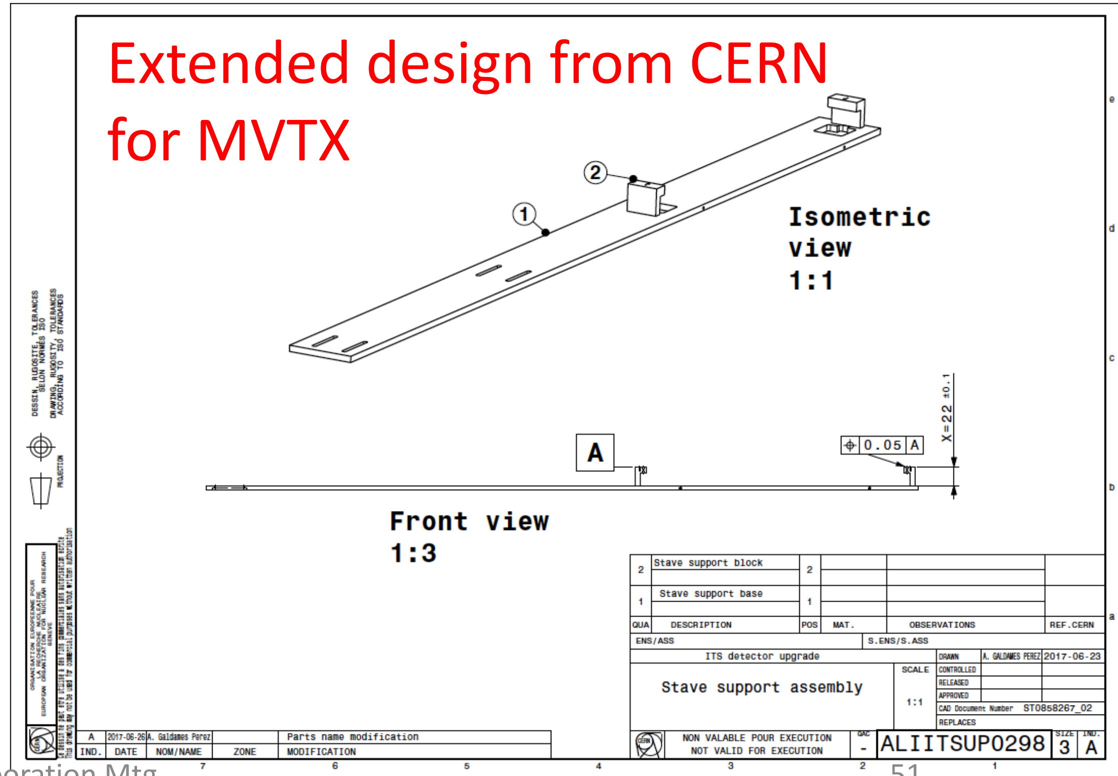
Readout Units

- 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

Stave Production and Shipping etc.

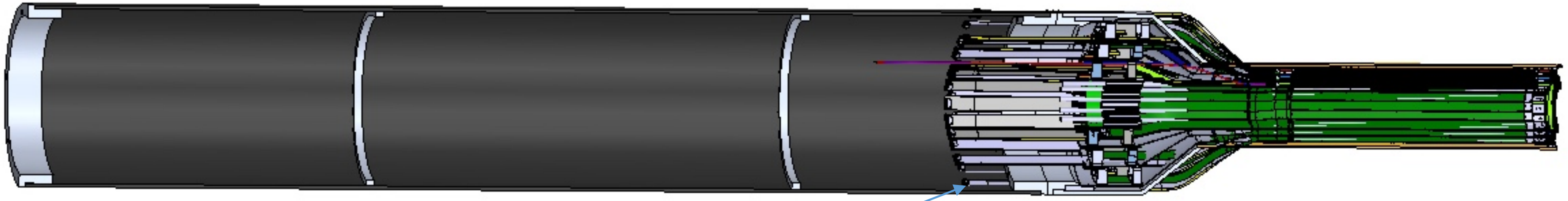
- Hand carry staves from CERN to LBNL, 4 trips
- Preliminary design from CERN for stave transportation plates
    - To be produced at CERN, paid by LBNL/sPHENIX



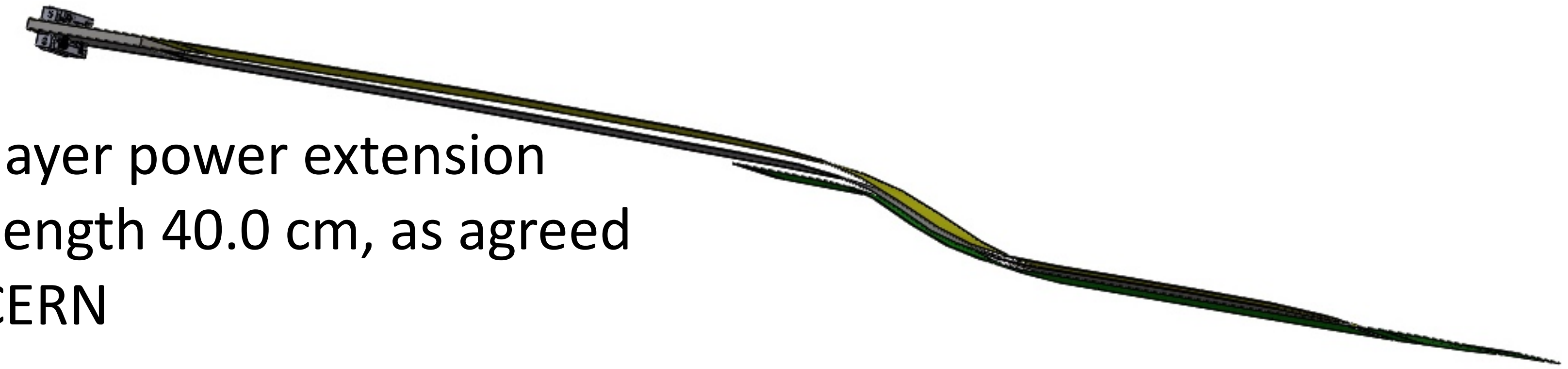


MXTX Model with Correct Length Power Cables:

Ross's talk

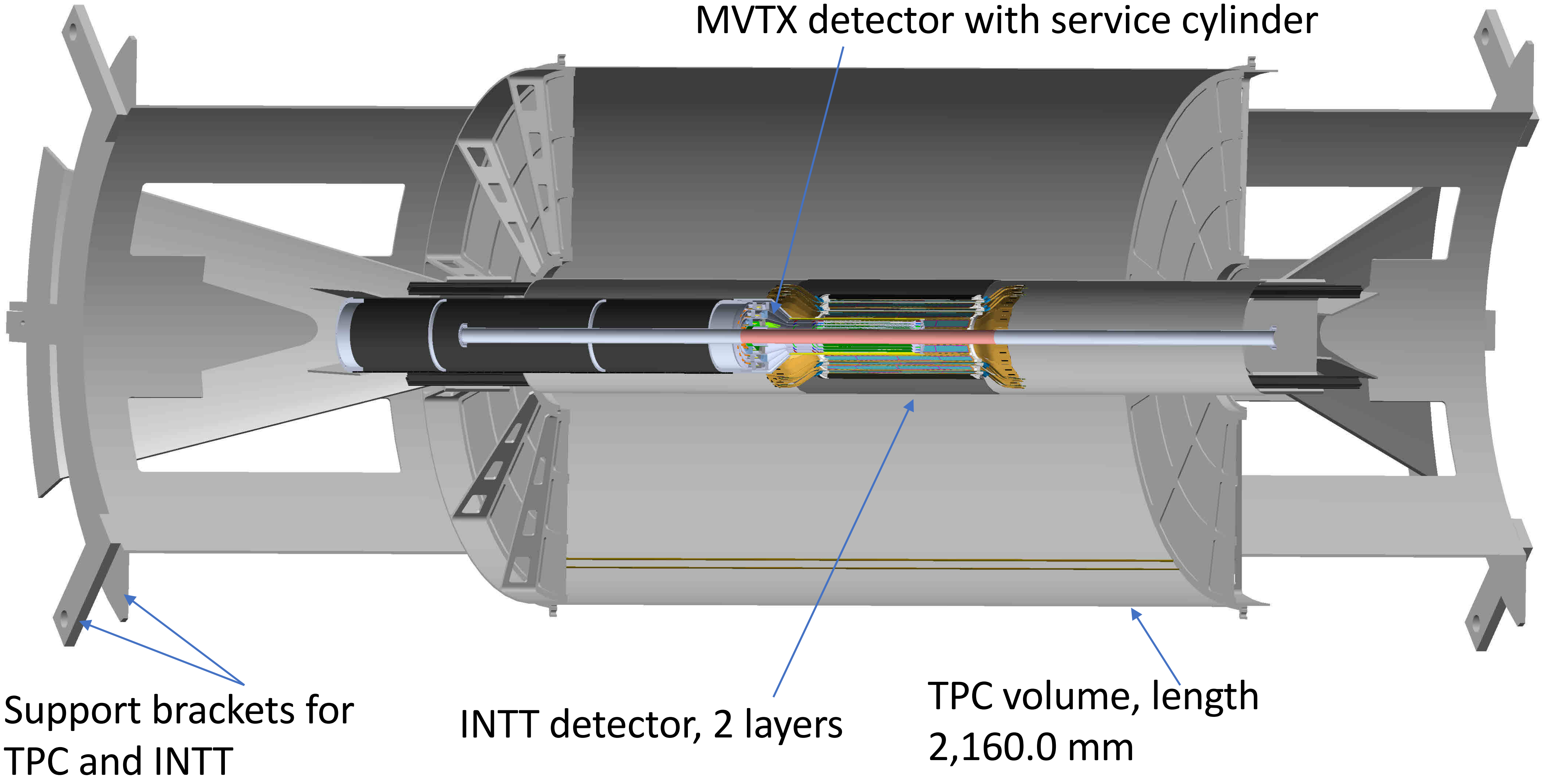


New shorter 40 cm overall length for power extension cables from stave, more than 220. mm shorter than was shown in previous model, same length service-barrel – 1200.0mm, location for a new patch panel 1B.



Updated inner layer power extension cable – overall length 40.0 cm, as agreed to by ALICE at CERN

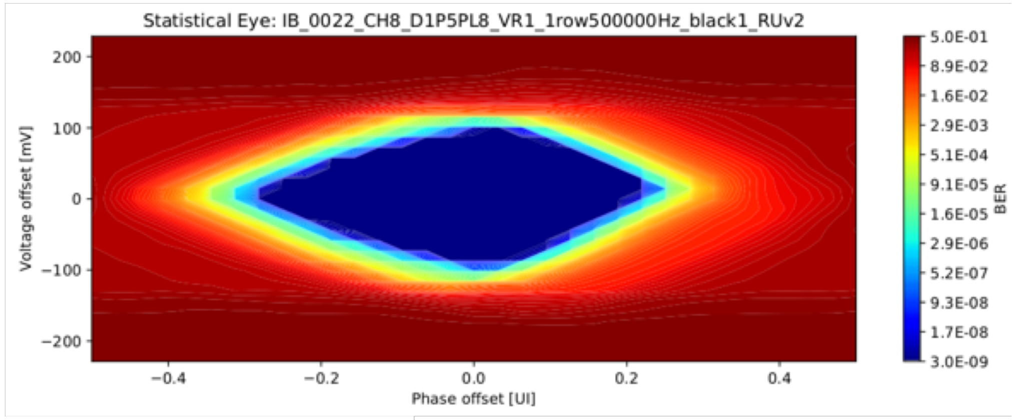
MVTX detector in sPHENIX



Signal Cable Design

From Sho

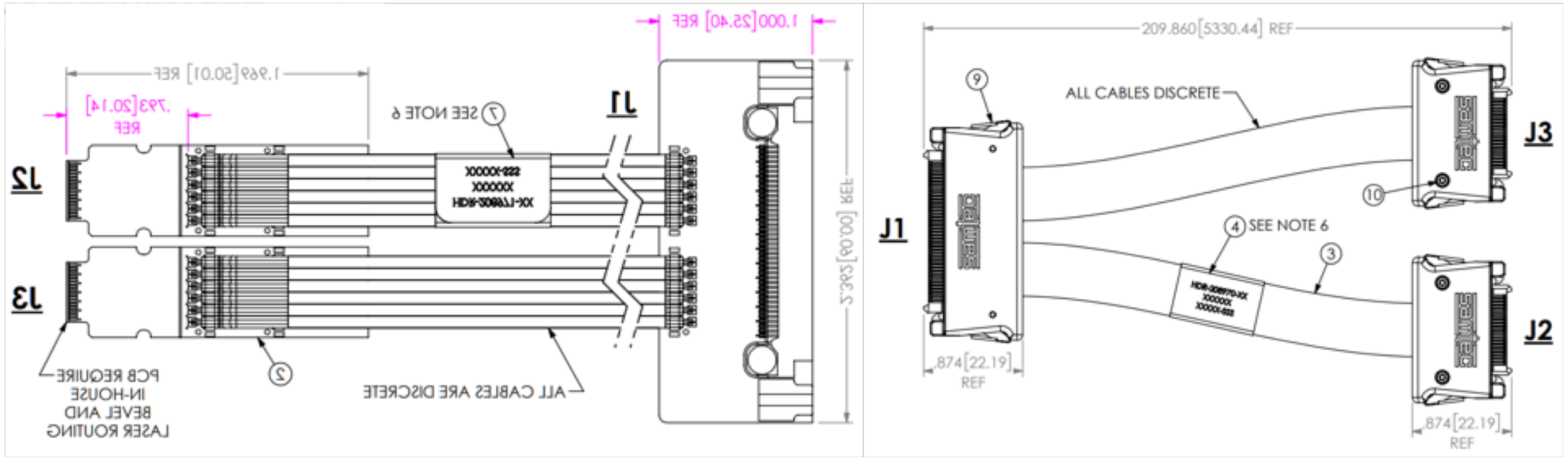
- The Samtec twinax cables carry clock (40 MHz), control (40 Mbps bidirectional), data (9x1.2 Gbps)
- ALICE is using halogen-free cables (32 AWG, LDPE dielectric) due to CERN LSZH requirement; 2.65 + 5.3 m cables have been tested and are now in production



CCS-183564-XX-03-TB	
Parameter	**Reference value**
Impedance tolerance [%]	100Ω ±5%
Maximum insertion loss [db @ 1GHz for 1m]	-1.72 dB
Maximum return loss [dB @ 1GHz for 1m]	-18.40dB
Maximum within pair skew [ps/m]	10ps/m
Maximum pair to pair skew [ps/m]	50ps/m

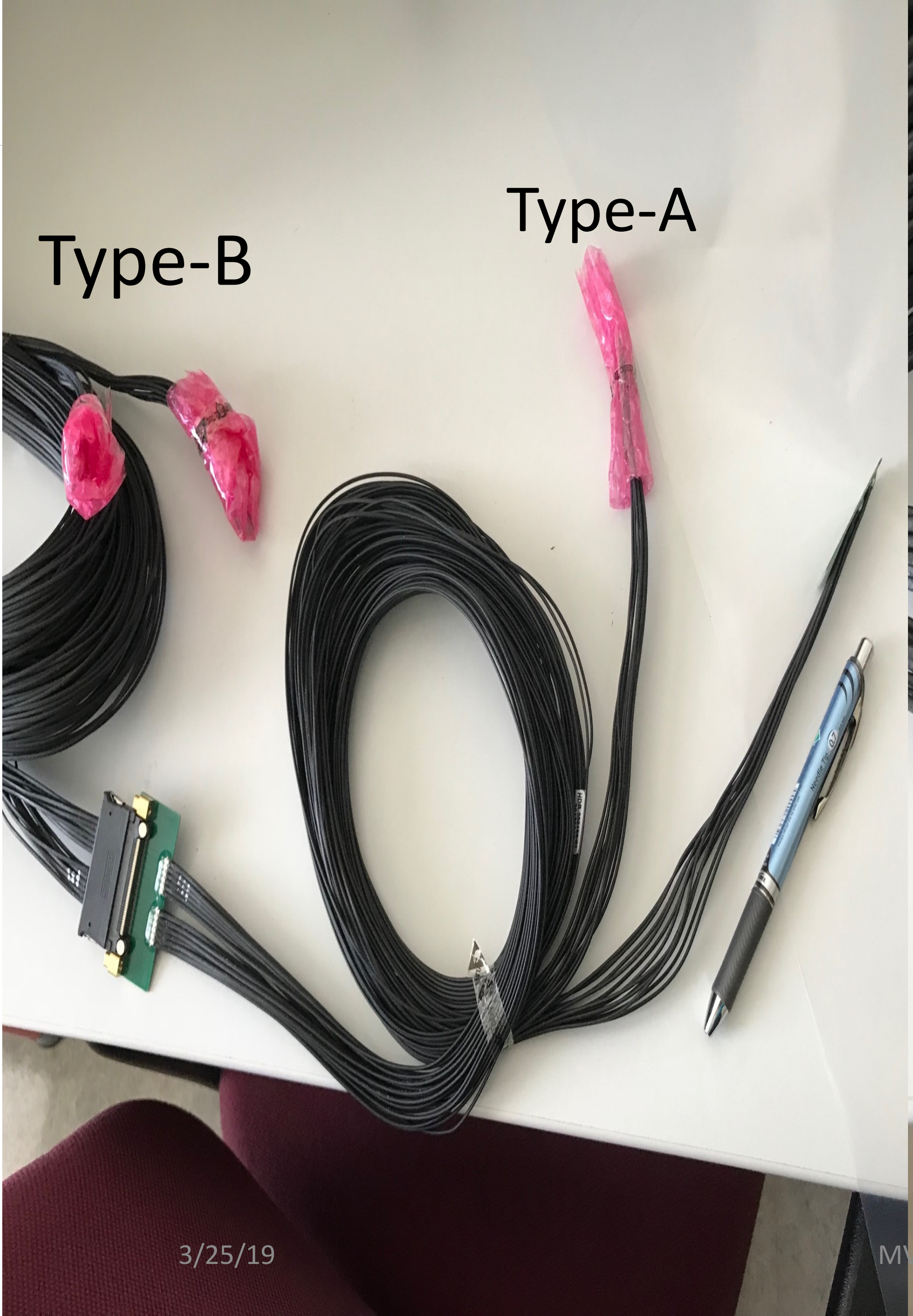
Stave

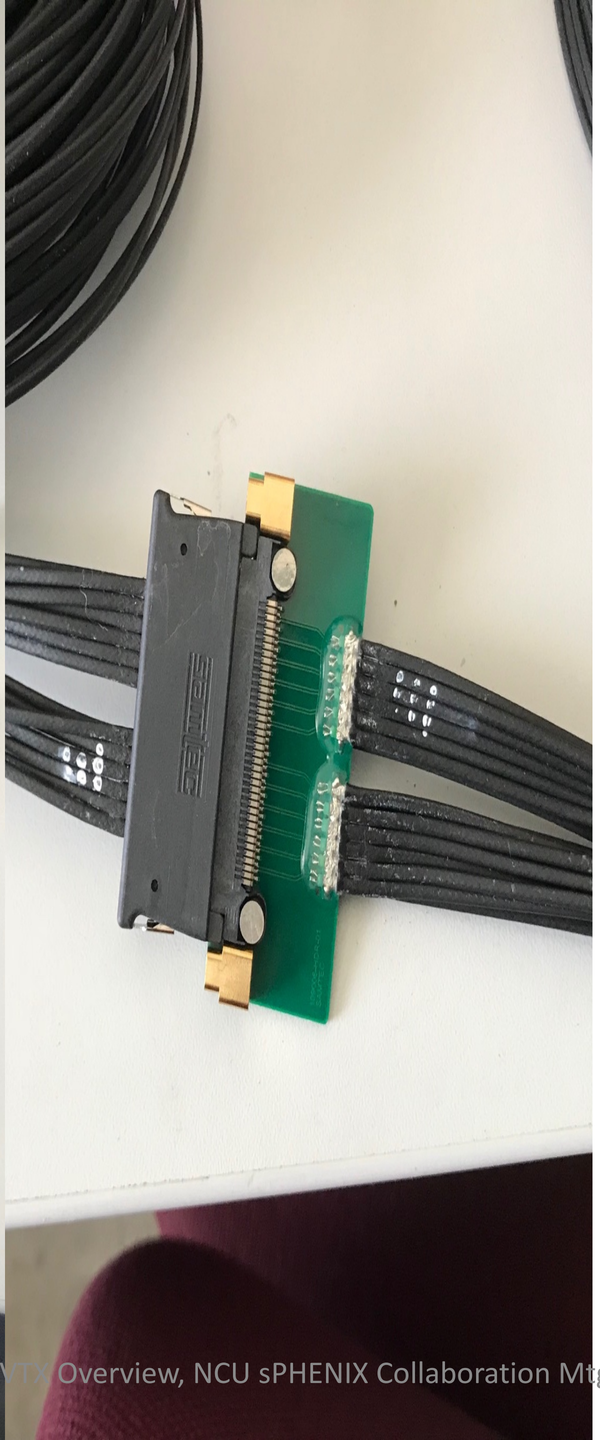
Stave



RU

RU

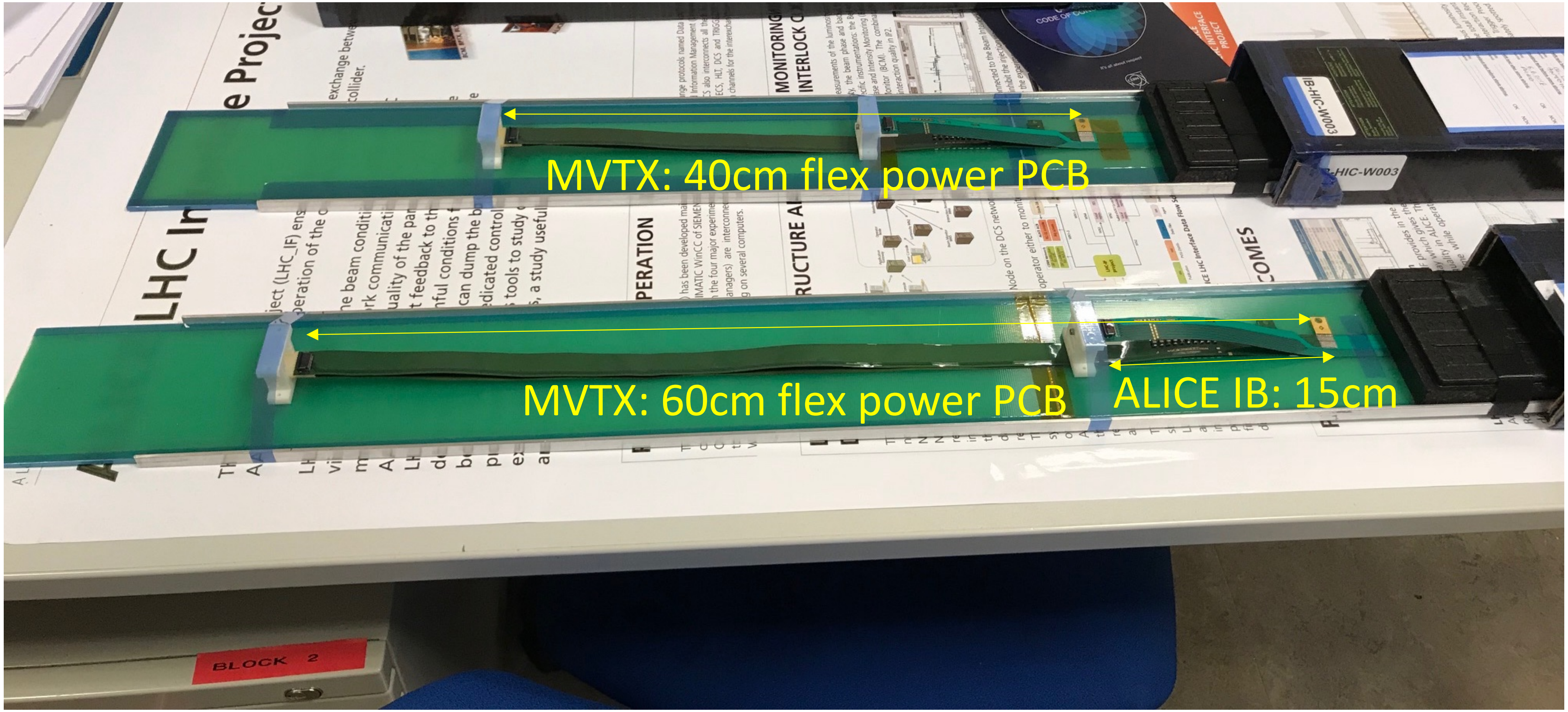

Type-B
Type-A




Type-A

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

NO noticeable difference in sensor performance, as expected, 9/2018



HICs Test Results from CERN (9/2018)

- 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**

After: same ALICE HICs, replaced power FPCs

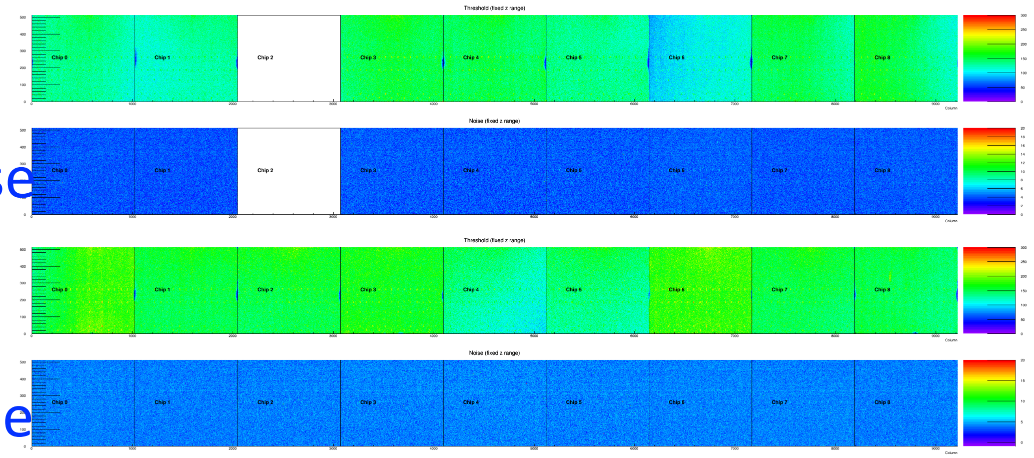
- top 40 cm, bottom 60 cm:

Thr.

Noise

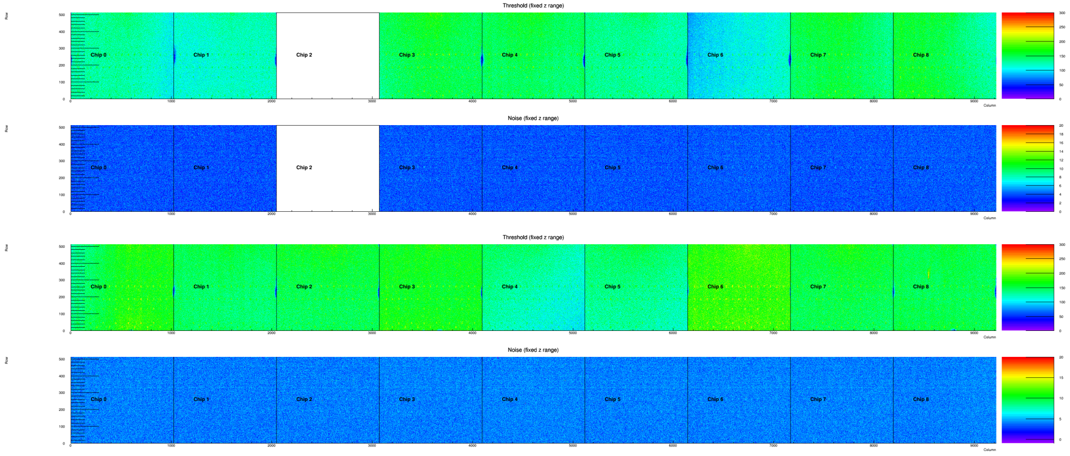
Thr.

Noise



HIC1

HIC2



Chip-0

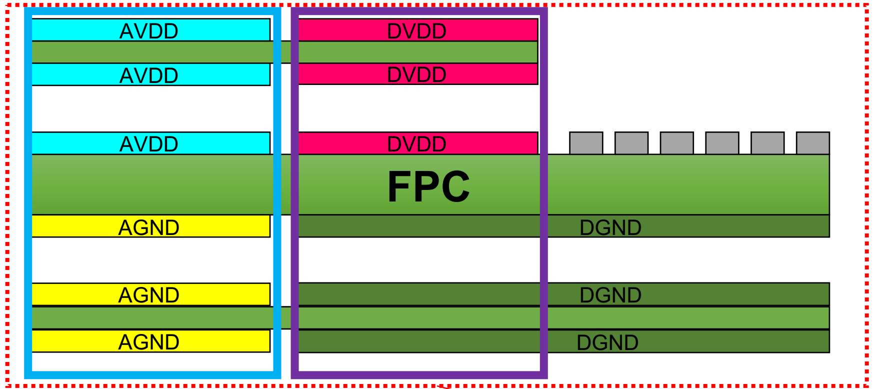
Chip-8

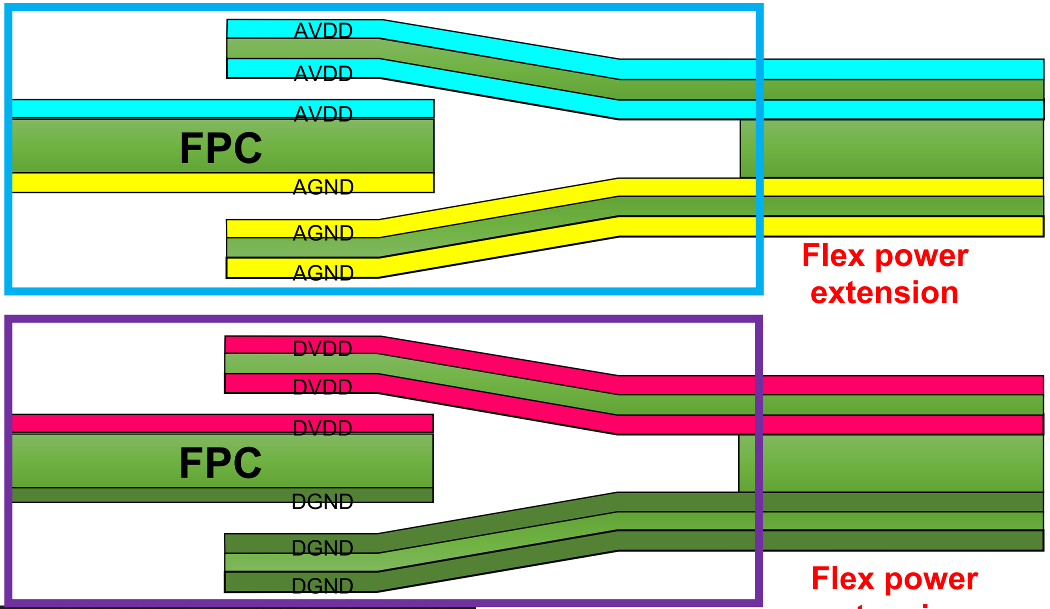
Noise level: ~4 e's; Threshold: ~180e's; MIP: ~1000 e's

FPC Extension for Connection to Electrical Services

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

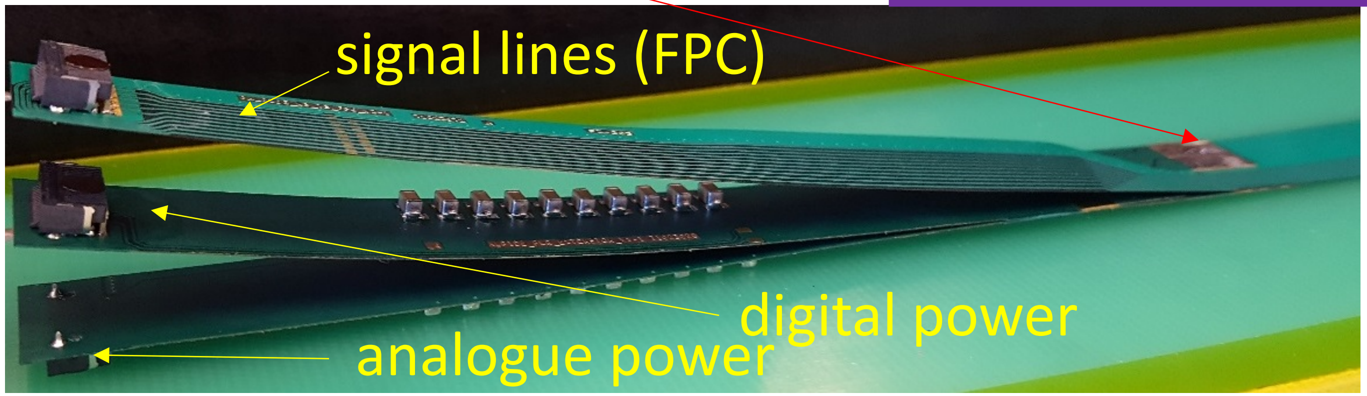
x-section at interconnection between FPC and extensions





Flex power extension

Flex power extension



Modified for sPHENIX: 15cm -> 40cm

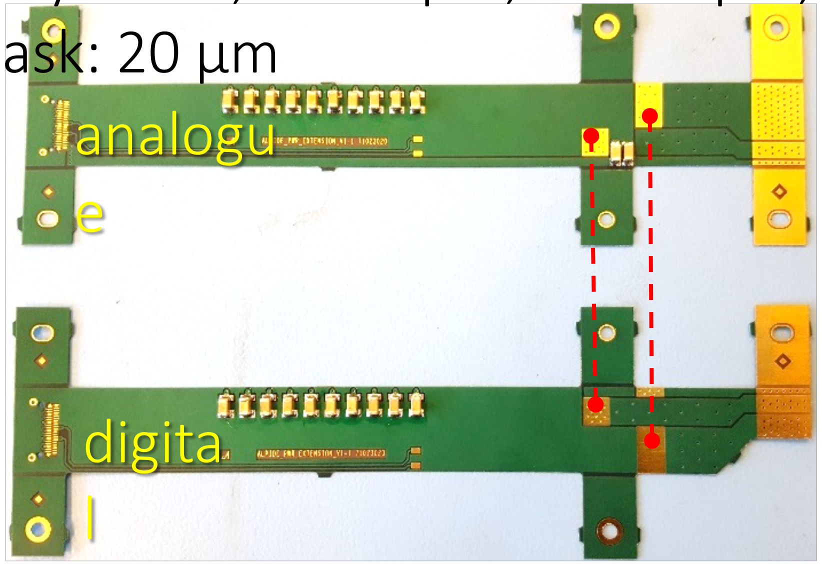
FPC Extension for Connection to Electrical Services

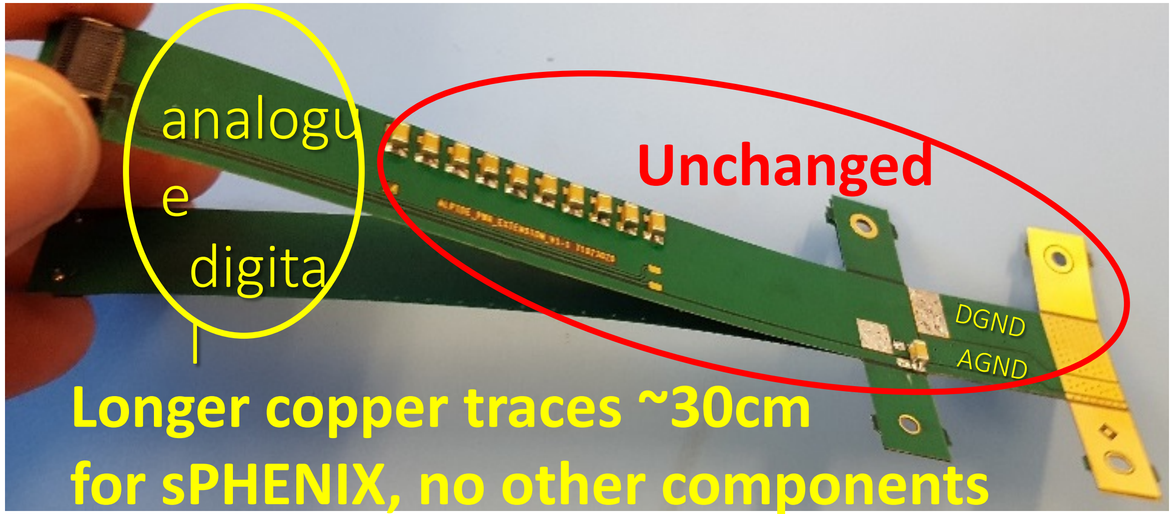
From Antonello Di Mauro

ALICE ITS Upgrade

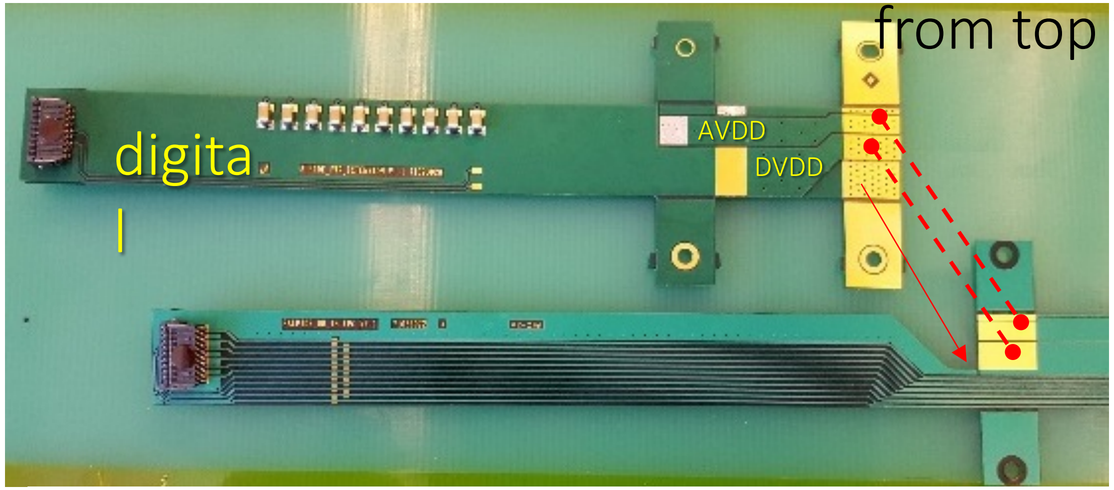
ALICE

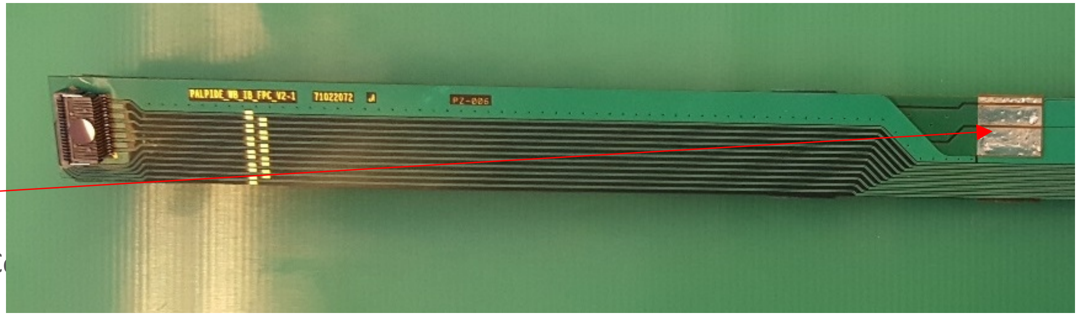
2-layer flex, PI: 50 µm, Cu: 35 µm, solder mask: 20 µm





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

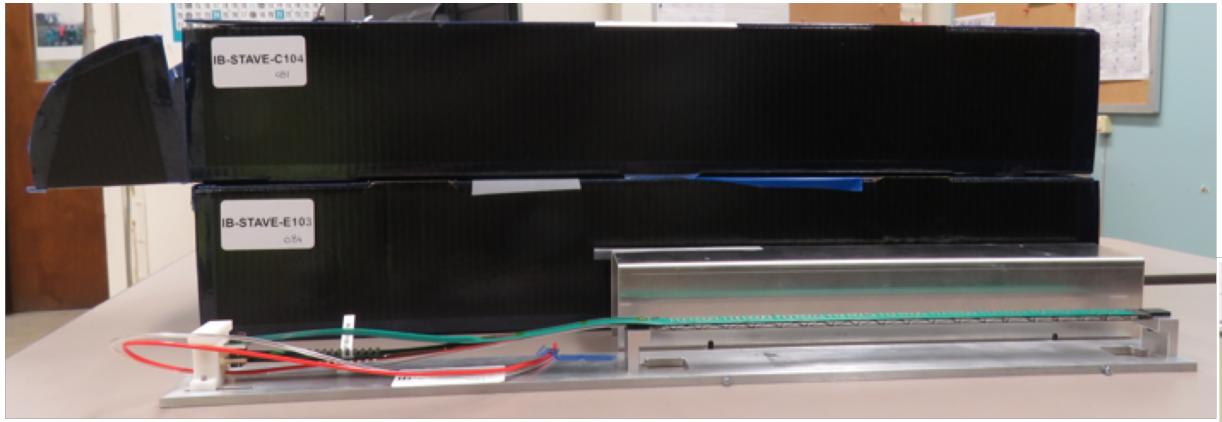


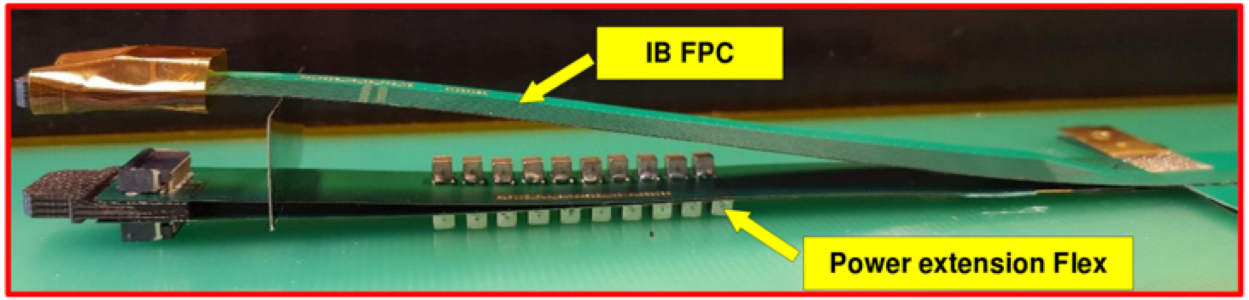


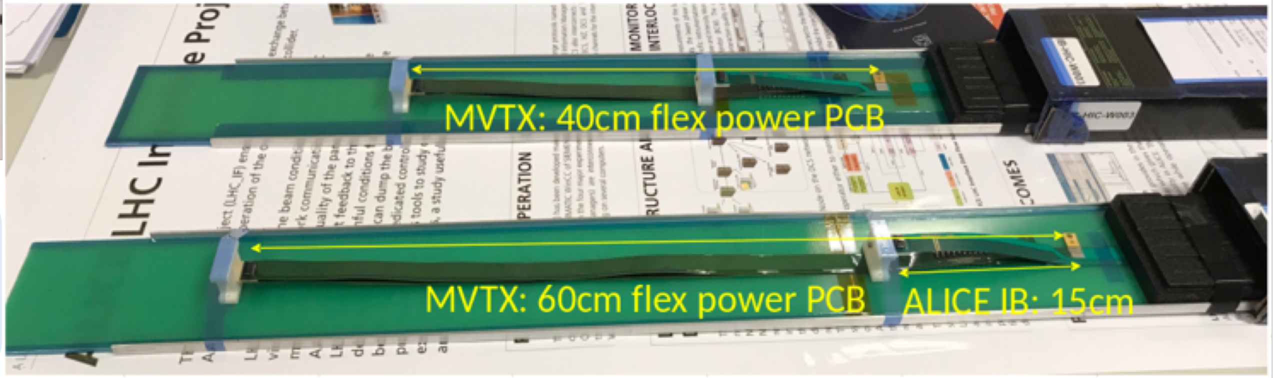
The PWR extension is connected to the FPC by iron soldering and wings are cut.

Stave

- Production stave consists of three flex circuits: one signal FPC that carries the ALPIDE sensors, two power FPCs that carry AVDD and DVDD
- For MVTX mechanical integration, the power FPCs must be lengthened to 40 cm (from 15 cm)
    - We qualified 40 and 60 cm FPCs at CERN: identical performance
- 4 staves at LANL







MVTX stave modifications have been qualified, and we have our first 4 staves

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

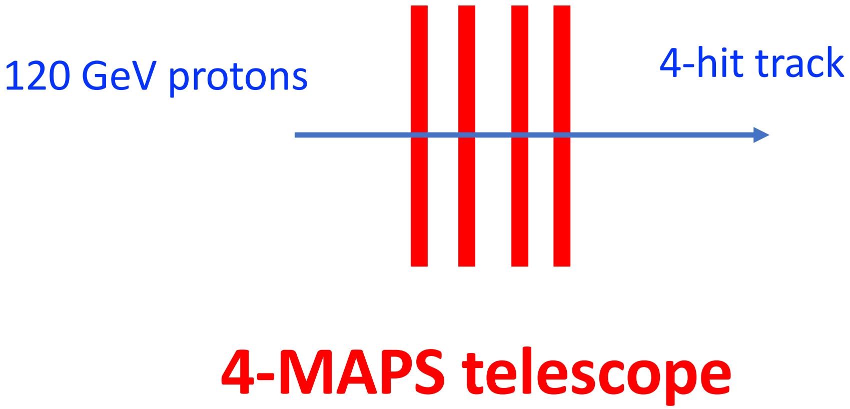
1. Prepare sensors and FPC
2. Glue 9 sensors to FPC
3. Wire bonding 9 sensors to FPC
4. Solder power flex PCB to FPC
5. Glue HIC to coldplate/carbon space frame
6. A stave is ready for QA
7. CMM

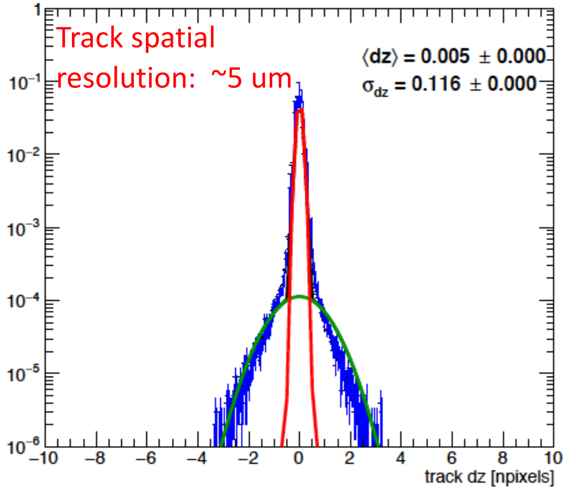
2018 Fermilab Test Beam Highlights

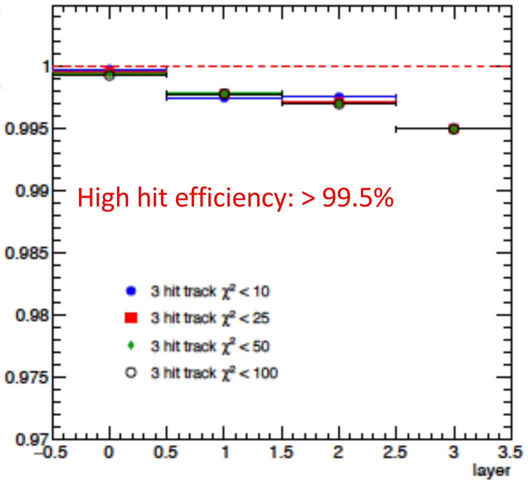
Sho's talk

Demonstrated full high-speed readout chain at Fermilab test beam in Feb - Mar 2018

- Sensors + RU + FELIX + RCDAQ/sPHENIX







LANL LDRD Activity Highlights

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