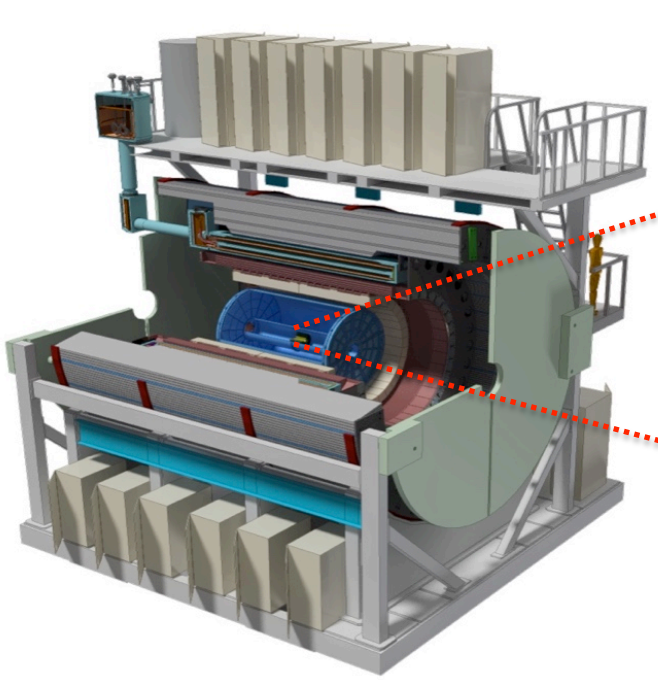
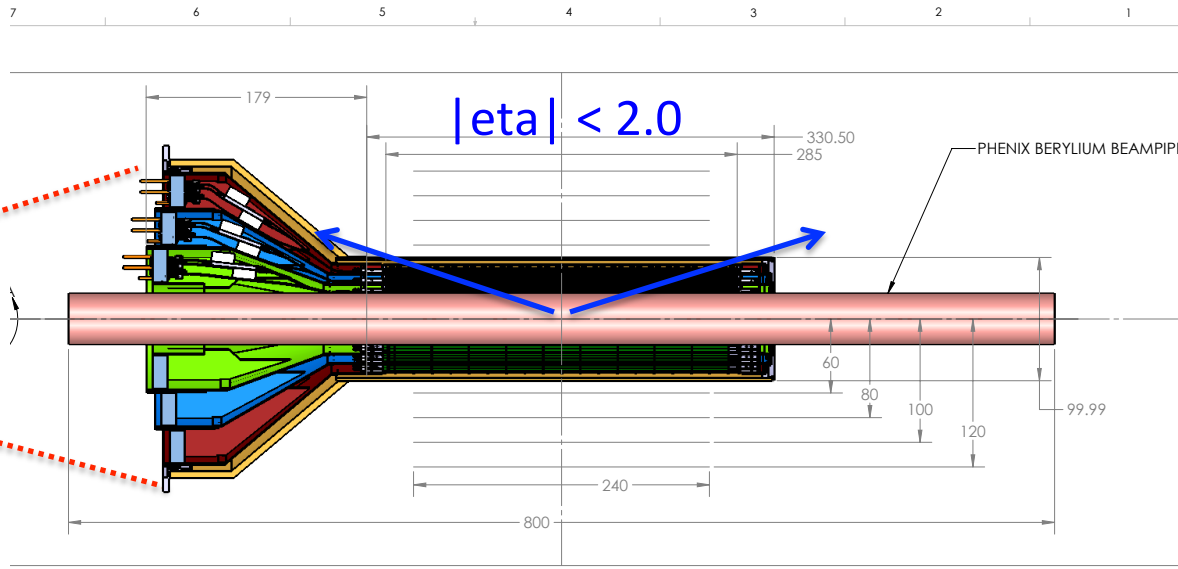
MVTX Status and Plan

Ming Liu
Los Alamos

MAPS-based Vertex Detector (MVTX)





R = 2.4; 3.2; 3.9cm;
L = 27.1cm

- "Adopt" ALICE ITS Upgrade Inner Barrel 3-layer MAPS detector
  - Mini. risk, Max. Physics
- Precision vertexing for b-jet/B-hadron tagging with high efficiency and high purity

- B-jet modification in QGP at low-medium pT to determine QGP properties, study mass-dependence on collisional vs radiative energy loss, flow etc.

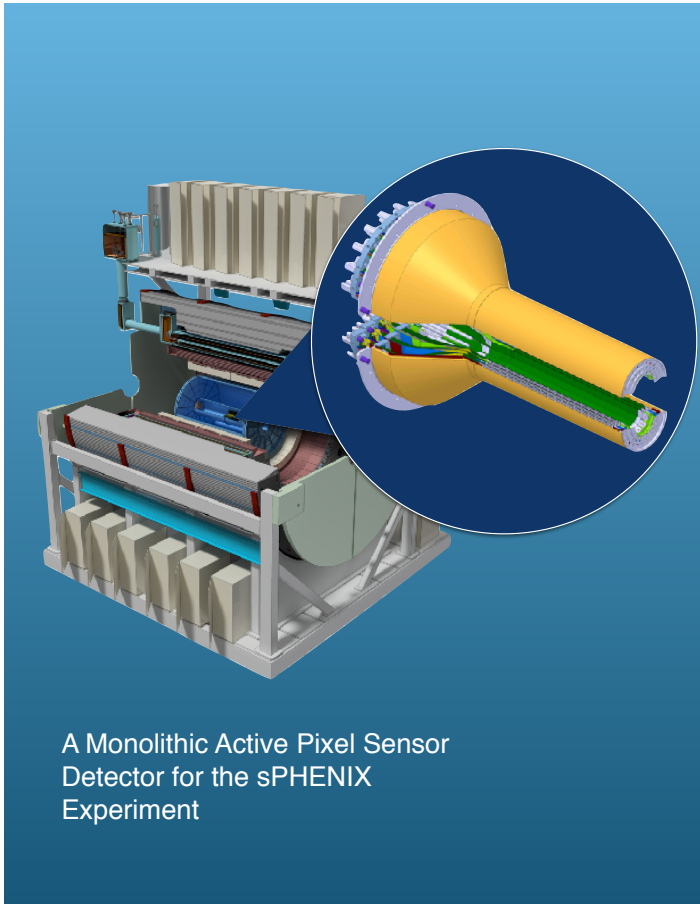
- A separate DOE MIE to build the full detector, WBS 1.12, ~$5M for construction;
- Early R&D by LANL LDRD, $5M, FY17-19, readout and mechanical integration;

Outline

- MVTX Pre-proposal
- BNL Director's review
- R&D status and plan
  - Stave
  - Readout
  - PS and Controls
  - MOSAIC test bench
- Mechanical integration
  - MVTX/INTT/TPC

MVTX Pre-proposal Submitted!

- Pre-proposal submitted to DOE, 2/2017
  - Follow-up discussions with DOE and BNL managers
  - Weekly proj. leaders meeting BNL/LANL/LBNL/MIT
- Plan to update proposal to DOE, late 2017
  - Expanded science "CD0" + Cost & Schedule "CD1"
  - Funding in FY18, stave production @CERN in Aug. 2018+, ~6 months;
    - Other options being explored for stave production @CERN/CCNU for delayed funding
- BNL Director's Review: July 10-11, 2017
  - Expand science case, "CD0"
  - Update Cost & Schedule, "CD1"
  - A dry run next Monday 6/19



A growing collaboration!

new sPHENIX/MVTX members:

- Czech groups
- CCNU – lab
- USTC
- Peking Univ.

A great opportunity for:

- Physics
- Detector R&D
- Hardware
- Offline software

7 Organization and Collaboration

Here we discuss the current collaborating institutions and their focus areas. Based on their technical expertise and available resources, LANL, LBNL and MIT/Bates groups are leading the three major technical tasks of the project: 1) readout electronics integration; 2)carbon mechanical support frames production and 3) cooling and mechanical system integration, respectively.

Los Alamos National Lab (LANL) : Readout electronics and mechanics integration.

Lawrence Berkeley National Lab (LBNL) : Carbon structure, production, LV and HV power system, full detector assembly and test.

Brookhaven National Lab (BNL) : System integration and services, safety and monitoring.

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

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

University of Texas at Austin (UT Austin) : MVTX readout electronics integration and testing.

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

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

Florida State University (FSU) : Offline and simulations.

University of New Mexico (UNM) : LV cabling & connectors.

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

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

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

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

Yonsei University (Korea) : MAPS chips QA and readout, simulations

RIKEN/RBRC (Japan) : Mechanical integration, cooling, cabling, simulation, patter recognition.

Purdue: Detector assembly and testing, analysis. Silicon lab available.

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

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

Scope of the MVTX Project

- MAPS staves & Electronics
  - MAPS Detectors
    - "MoU" to build 68 ITS MAPS staves
    - No modification
  - Readout Electronics
    - Frontend: ALICE/ITS, RU
    - Backend: ATLAS FELIX
    - Modify/reprogram RU & FELIX for sPHENIX
    - **R&D by LANL LDRD**
  - Production
    - Extend ALICE/ITS MAPS stave production
    - sPHENIX personnel help assembly and testing staves at CERN
    - Reproduce additional ALICE RU & FELIX for sPHENIX
    - Final assembly and test in US, LBNL/BNL
  - Ancillary systems, copy ALICE
    - LV/HV, cables, crates, racks etc.
    - Slow control, safety and monitoring
- Mechanics & Cooling
  - No/(some) 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
    - Design integration frames
    - Carbon frames etc.
    - Installation tooling etc.
  - Copy ALICE cooling plant design
    - Minor modification to fit sPHENIX
    - Smaller heat load than ALICE ITS
  - Metrology and Survey

WBS 1.12: a new MIE fund the full MAPS Vertex Detector, ~$5M

Project Tasks and Timeline

sPHENIX baseline

CD-0 9/2016

CD-1

CD-2/3 8/1

Ready for Beam 6/1

ALICE ITS/IB Prod. ends

Key R&D

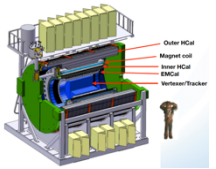
Readout R&D Mech. design @LANL/ALICE

Mech. Integr. & Prototype @MIT/LBNL

A schedule driven project!

Production

MAPS Prod. & QA @ALICE → Stave prod.&test @CERN; "RU" prod @CERN "FELIX" Prod. @US → Detector Assembly & Test @LBNL → Det. Install. @BNL



+2% +50%

"MoU" w/ ALICE/ITS: 11/2016

- Produce MAPS chips and Stave Space frames for sPHENIX as part of ALICE production!
- Full staves and RU & CRU production cost & schedule → **MVTX MIE**

Prepare for the BNL Director's Review

- Science
  - Preliminary for a dry run next week
    - B hadron physics
    - B-jet physics
    - Detector performance plots
  - Near final "money plots" for July review

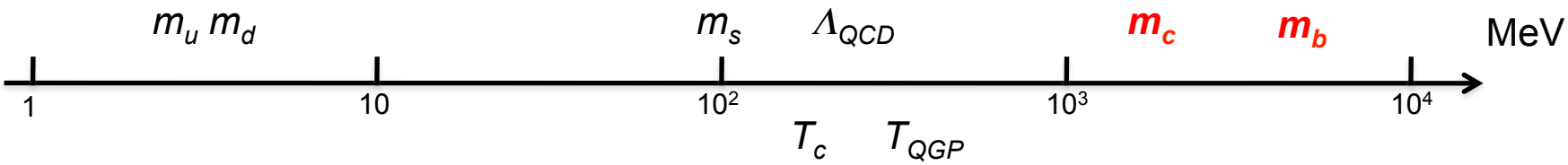
HF-Jet Topical Group

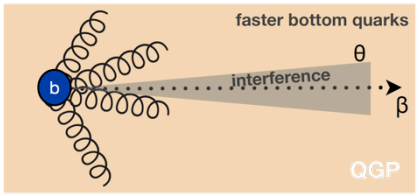
- Cost and Schedule
  - Updated WBS structure and org chart
  - Work in progress, cost & schedule, 6/5/2017

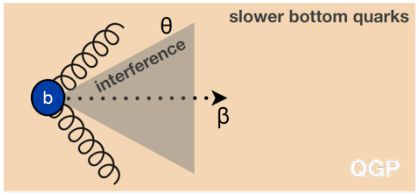
- MVTX stave production options
  - Ming's visit to CCNU in May
  - Maria's visit to CERN this week

Jin's Talk

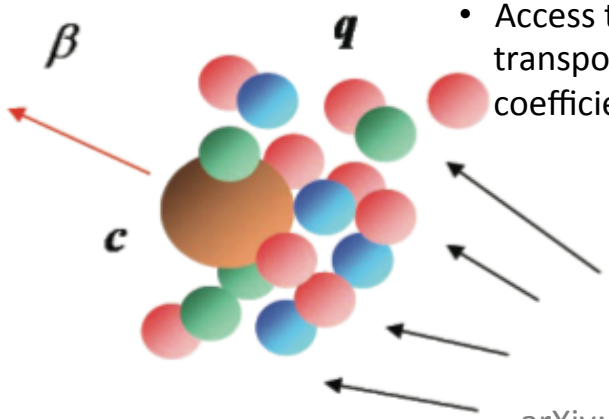
Uniqueness of Heavy Quarks in QCD



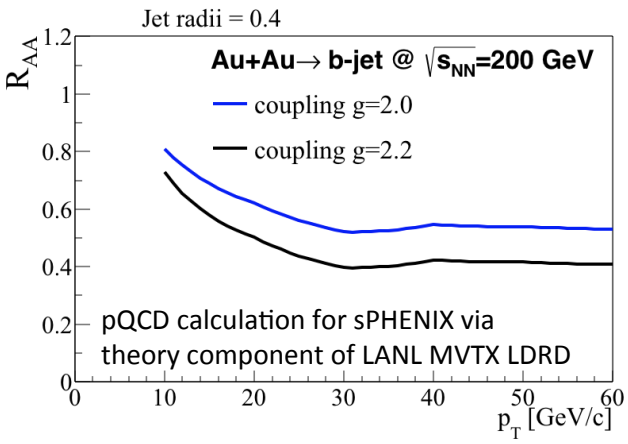


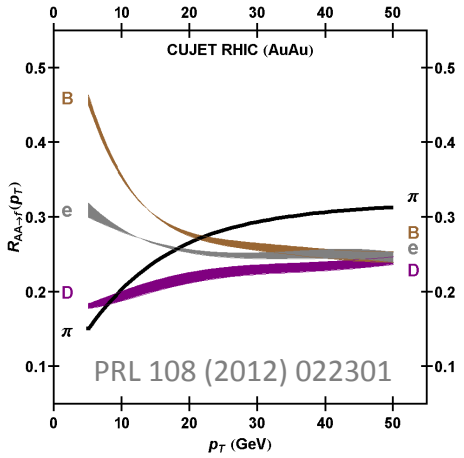


- differentiating sensitivity to collision VS
- radiative energy loss

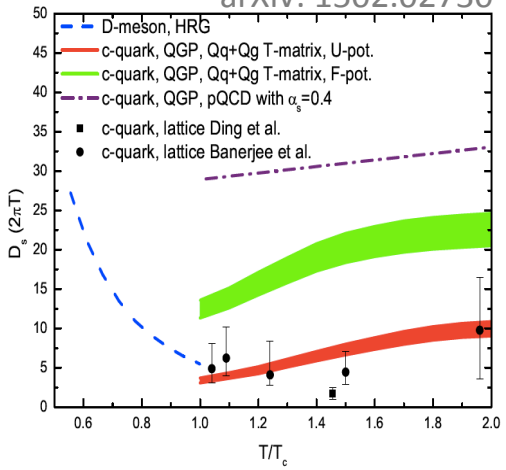


- Access the medium transport, such as diffusion coefficient D_{HQ}





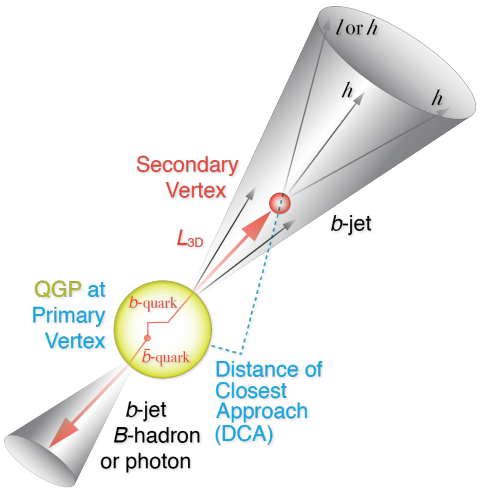
arXiv: 1502.02730

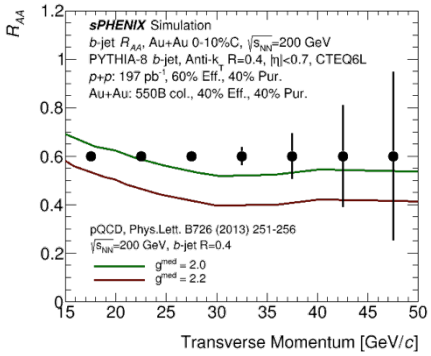


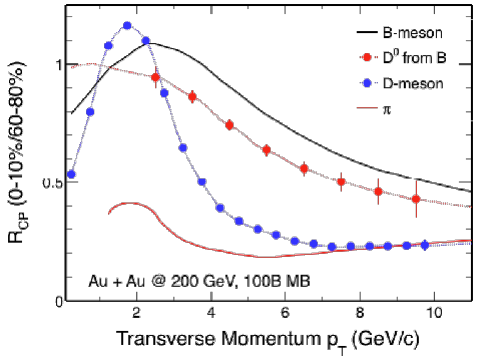
Jin's Talk

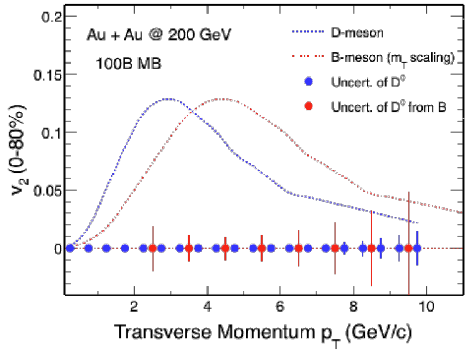
HF-topical group

- HF in sPHENIX: in particular B-meson and b-jets, provide differentiating sensitivity to collision VS radiative energy loss, access to HQ transport parameter of QGP, total cross section. Bring results to precision era.
  - $0<p_T<15$ GeV/c - *B*-meson: access down to zero pT, max sensitivity to HQ mass effect
  - $p_T>15$ GeV/c - *b*-Jet: less dependence on FF complication, probing parton kinematics and higher p_T-scale
- High priority task are set to develop and simulate performance for coming MVTX reviews and proposals, expanding the program in HF-jet and HF-meson programs







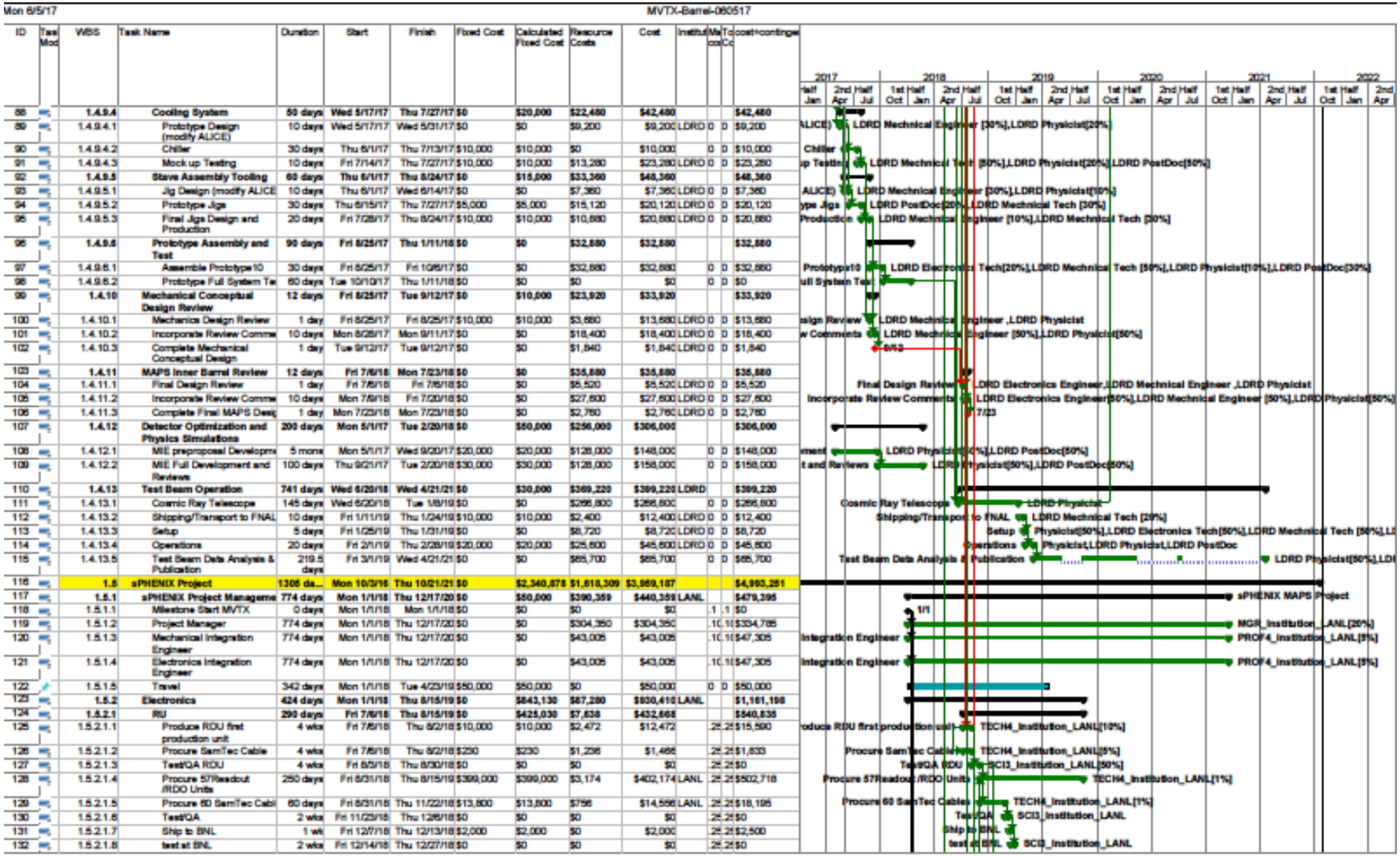


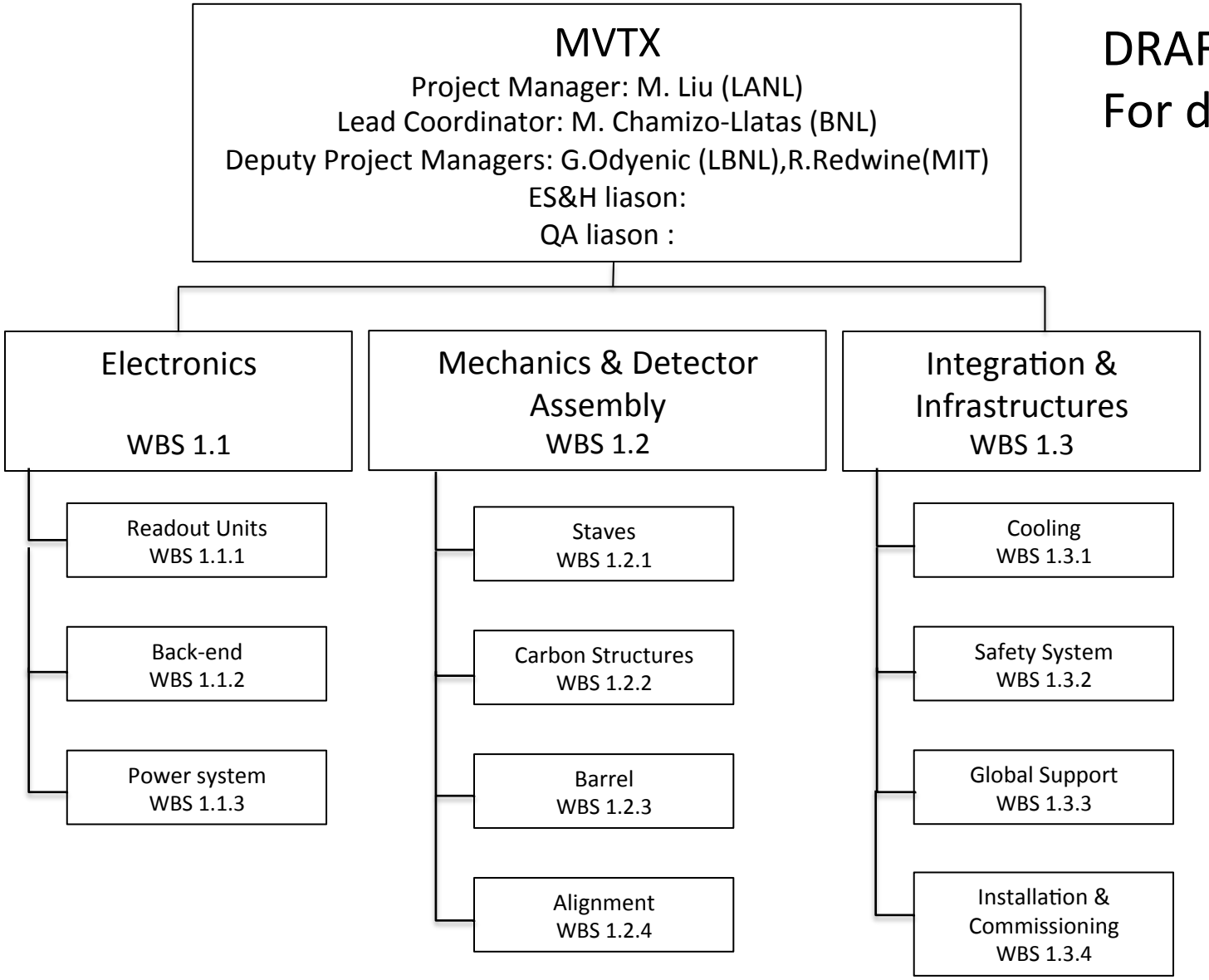
- Communication:
  - Discussion email list: https://lists.bnl.gov/mailman/listinfo/sphenix-hf-jets-l
  - Wiki page under construction: https://wiki.bnl.gov/sPHENIX/index.php/Heavy_Flavor_Topical_Group
- Meetings/Events
  - Use weekly simulation meetings for updates, https://indico.bnl.gov/categoryDisplay.py?categId=88
  - Monthly TG meetings: https://indico.bnl.gov/categoryDisplay.py?categId=151
  - Goal oriented irregular events:

    MVTX brainstorming meeting, Mar 8 / MAPS+HF-jet joint workfests, e.g. Jan 5-7 2017 @ Santa Fe / Pre-collaboration meeting work-fest on May 16-17, 2016 / Initial TG meeting on Apr 22 , 2016

Updated Cost and Schedule WBS: 6/5/2017

Dave Lee et al





DRAFT May 4
For discussion

MVTX R&D Status and Plan

- Readout R&D
  - 5 single-chip MAPS tested at LANL
  - Workfest @UT-Austin, 4/19-20
  - RUv1 available in July, will be used for LDRD telescope
  - BNL/ATLAS FELIX being evaluated as the default backend
    - Computer arrived, fibers/cables ordered
    - Obtain one FELIX in a few weeks
    - "CRU" being prototyped with Altera evaluation boards, able to communicate with the RUv0 board @ UT-Austin;
  - **LANL MOSAIC test bench in operation!**

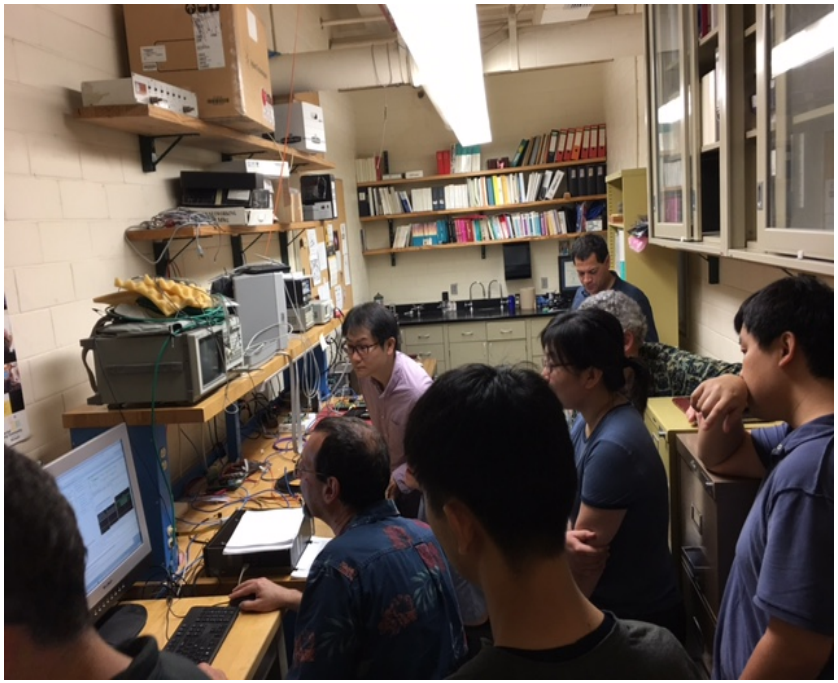
- Tracker integration task force
  - MVTX + INTT + TPC mechanical system integration
  - Identified the major tasks

- Stave production @CERN
  - ALICE Stave Production Readiness Review 4/27, prod. Starts in June/July
  - LANL people do assembly and testing at CERN, May – Sept. 2017
  - MVTX plan

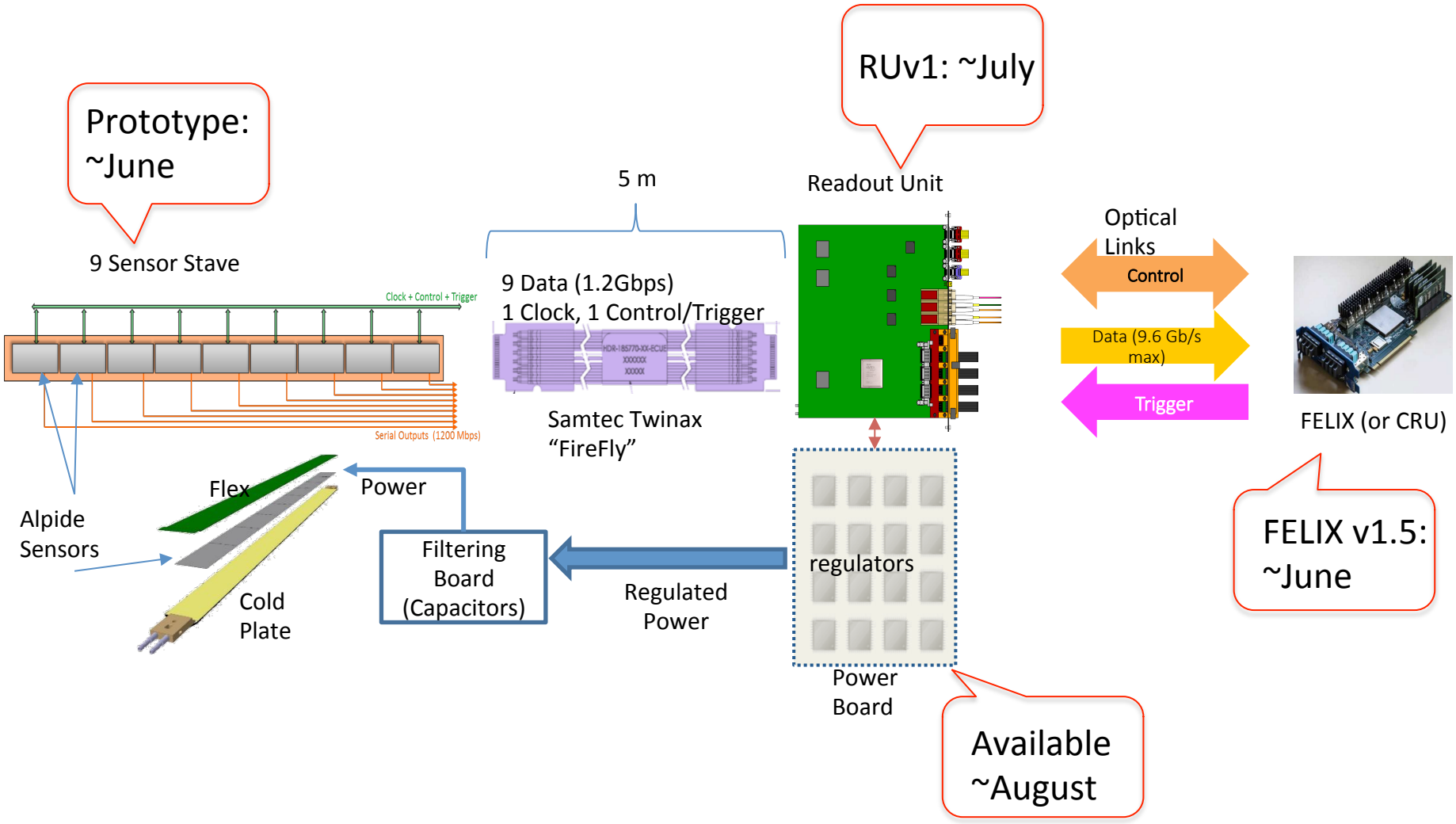
MVTX Readout Workfest @UT-Austin, 4/19-20

https://indico.bnl.gov/conferenceDisplay.py?confId=3047

- Very productive discussions:
  - sPHENIX readout – Martin
  - TPC readout – Jin and Takao
  - ALICE ITS readout system – Jo
  - LV/HV and Slow controls - Giacomo
  - MVTX readout options – Mark
- Lab demo of RUv0 and "CRU" R&D
  - RU v0
  - "CRU" prototype with an Altera eval. board
- A brief summary
  - Defined a possible MVTX readout path
    - RDO Unit, some modification
    - CRU/FELIX (TPC), significant R&D needed
  - Joint R&D on RU and CRU, maybe also FELIX integration
  - UT-Austin's interest in RU and CRU production & test!



MVTX Readout and Control System Status

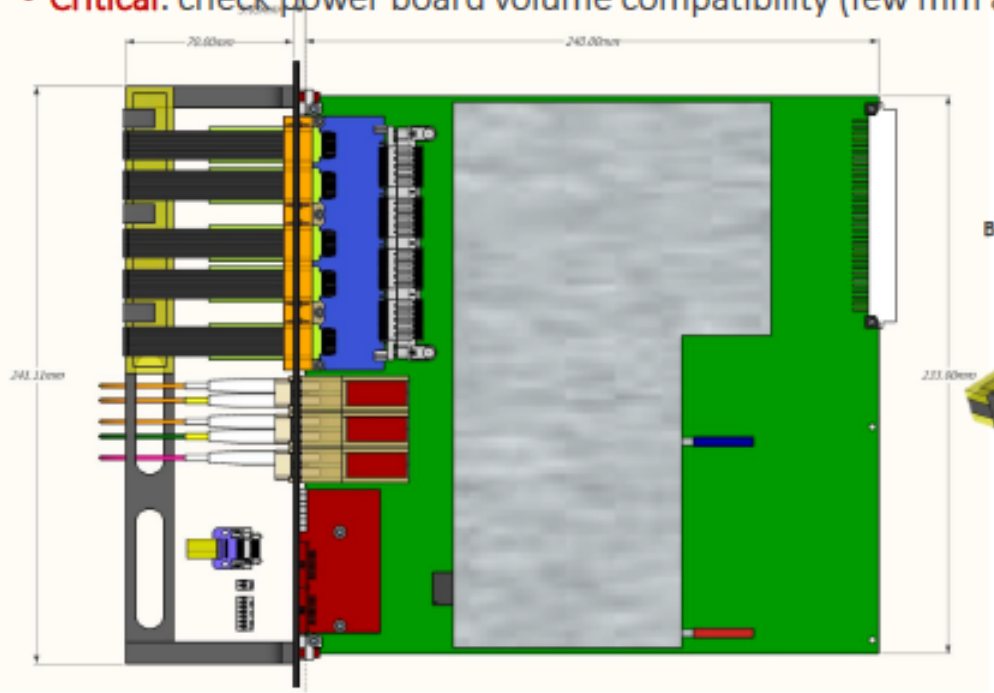


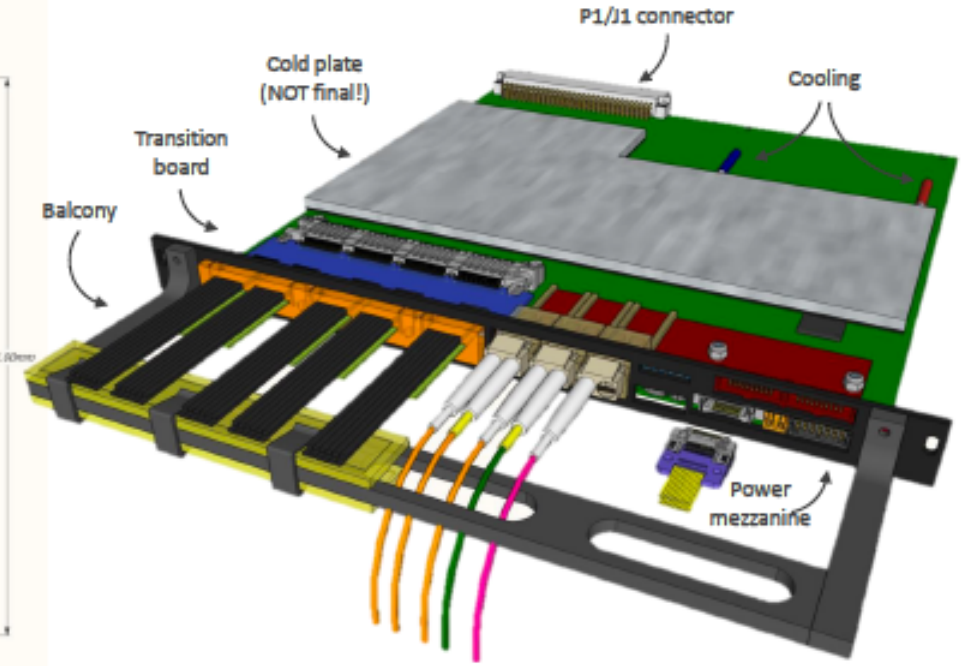
ALICE/ITS Readout R&D

5 RUv1 available for LANL R&D ~July 2017

RUv1 – Overview (board general layout an connectors fixed)

- All connectors fixed (connectors toward Power Units mounted on mezzanine, upgradable).
- PCB size 233 × 240 mm², VME slot compliant, VME J1 for power/ground. (1 – 1.5 kg cold plate included).
- ITS crates will accommodate 340mm deep Power Boards, a passive extender is envisaged.
- P1/J1 positioning makes the RUv1 vertical orientation FIXED (data connectors on top)
- Critical: data cable connector length (Antoine design) vs balcony depth (70mm now)
- Critical: check power board volume compatibility (few mm available on top side of RUv1 in case)

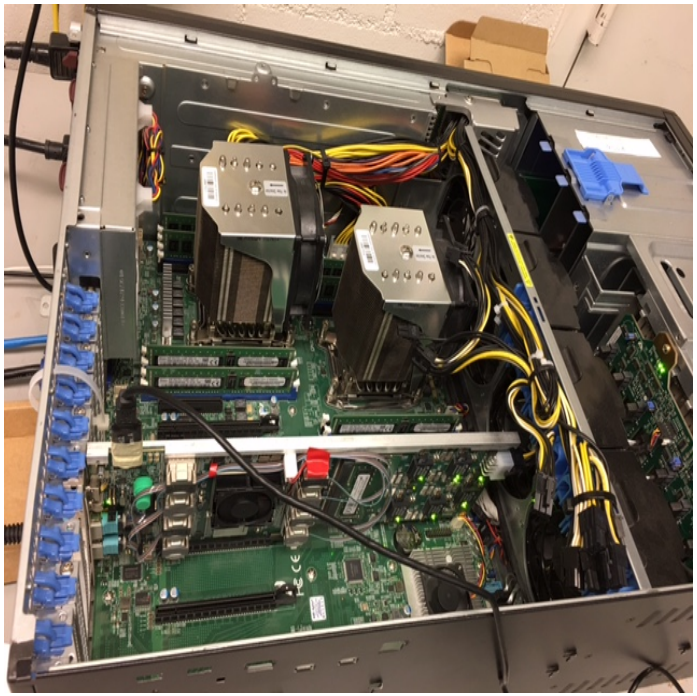




Electronics R&D – Cont.

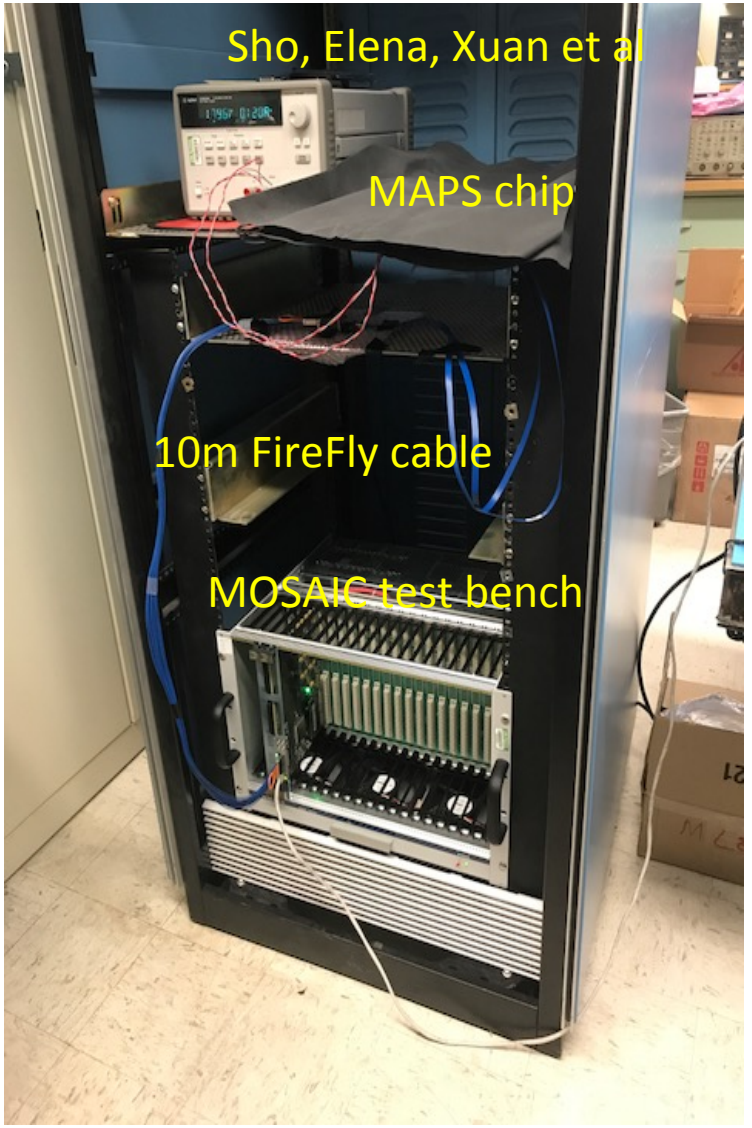
FELIX and MVTX Power Distribution Boards

- FELIX: visited BNL Labs and had FELIX system demo
  - V1.5 boards, all functionalities available- data, slow control and Timing/Trigger/Busy, w/ GBT
  - Multi-channel GBT links and PCIe interface code developed, with examples of user modules
  - V2.0, available ~end of 2017, sPHENIX application
  - A 1.5v FELIX board produced and tested, ready for shipment to LANL; Optical cables etc. to be ordered soon for LANL test bench
- Power distribution boards and PS
  - LBNL PS distribution board available for R&D from CERN/ LBNL ~ August. Order placed, 4wks + testing
  - R&D power supply and control system ordered (CAEN), available ~August



R&D @LANL on MAPS Single Chip Readout

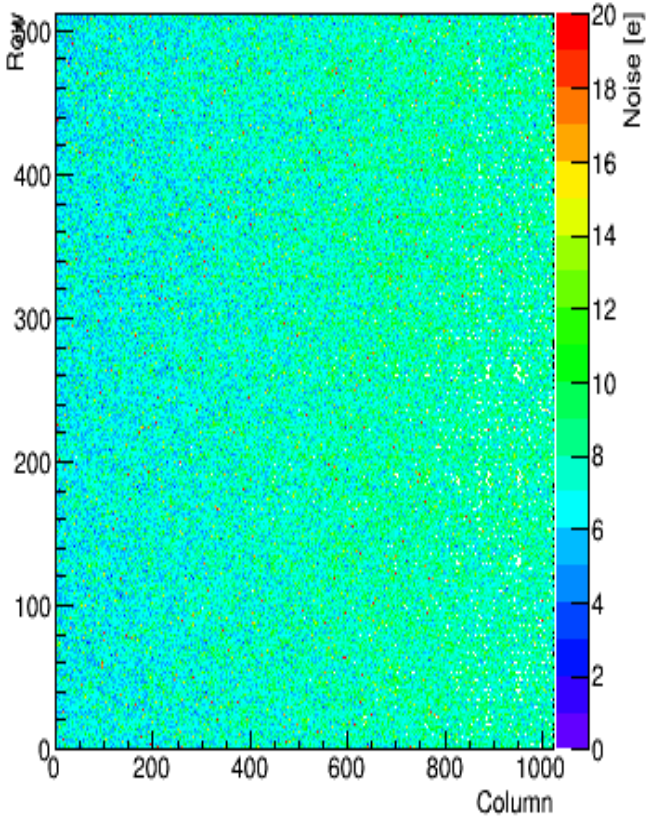
- MOSAIC test bench in operation
  - Single MAPS chip with high-speed readout
  - Threshold scan
  - Noise scan
  - External trigger
  - Test data readout performance
    - 1.2Gb/sec
    - 0.6Gb/sec
    - 0.4Gb/sec
- Test firefly cable performance
  - 5m (ALICE default)
  - 7m, 10m
  - Short extension cables, +20~30cm

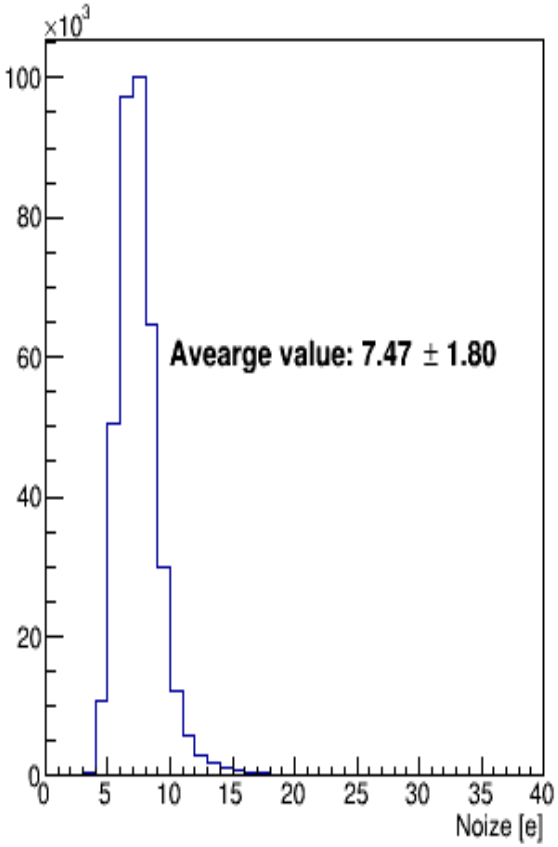


Test under internal trigger (40MHz)

From Xuan

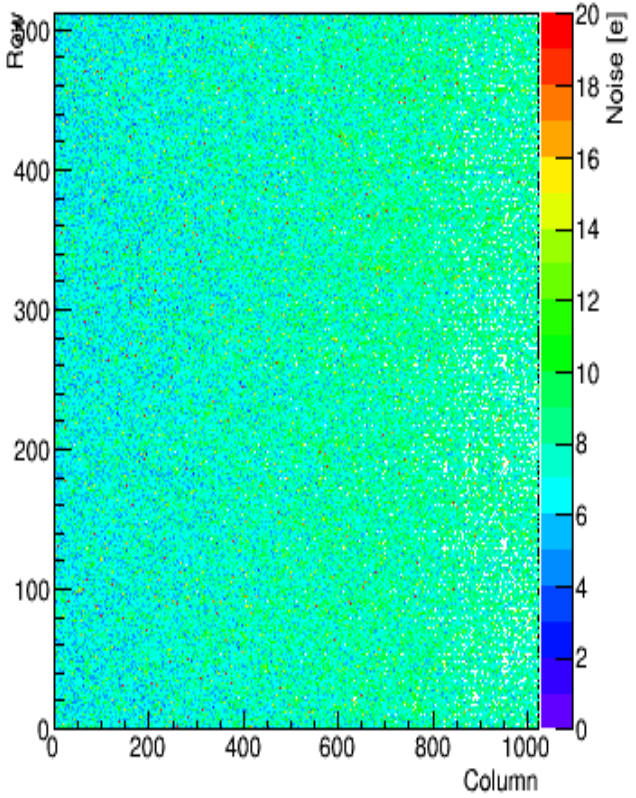
- Readout speed 1.2 Gb/s and 50 injections.
- Scan the noise per pixel and the average value is 7.47±1.80 (e).

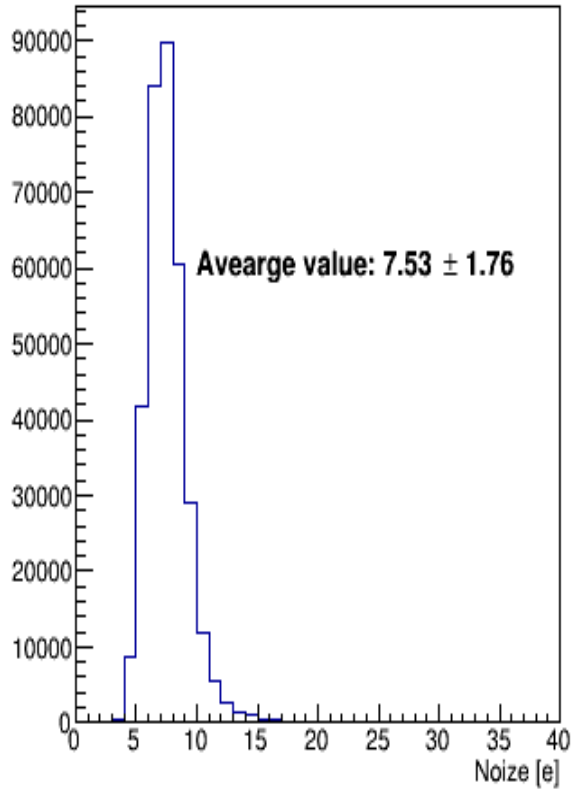




Test under internal trigger (40MHz)

- Readout speed 600 Mb/s and 50 injections.
- Scan the noise per pixel and the average value is 7.53±1.76 (e).

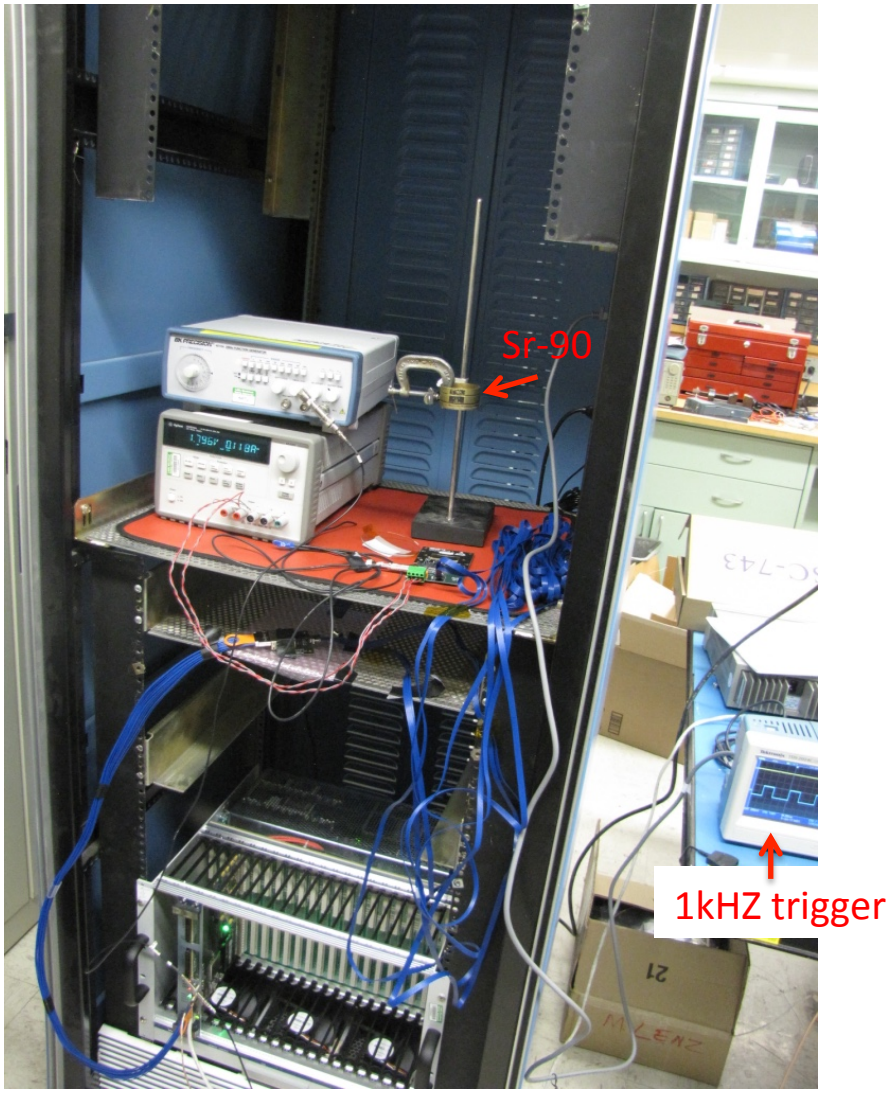




External Trigger and Source

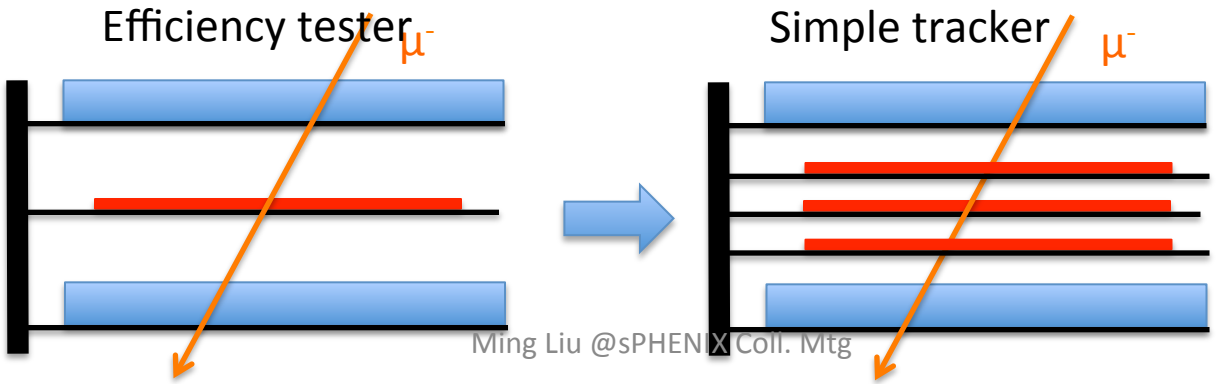
Xuan et al

- Single chip readout
- Use a pulse generator as the external trigger
- Use the Strontium-90 to produce beta rays.
  - Vary the distance between the source and the silicon chip



A Single-chip MAPS Telescope

- Check the readout occupancy and efficiency under different internal trigger clock (10-40MHz), readout speed (400-1200Mb/s) and threshold (set up by the analog signal or the configuration file?).
- Set cosmic ray triggers with scintillator bars or pads to read out single MVTX chip with the external coincidence cosmic ray trigger.
- Design of single chip based telescope in progress

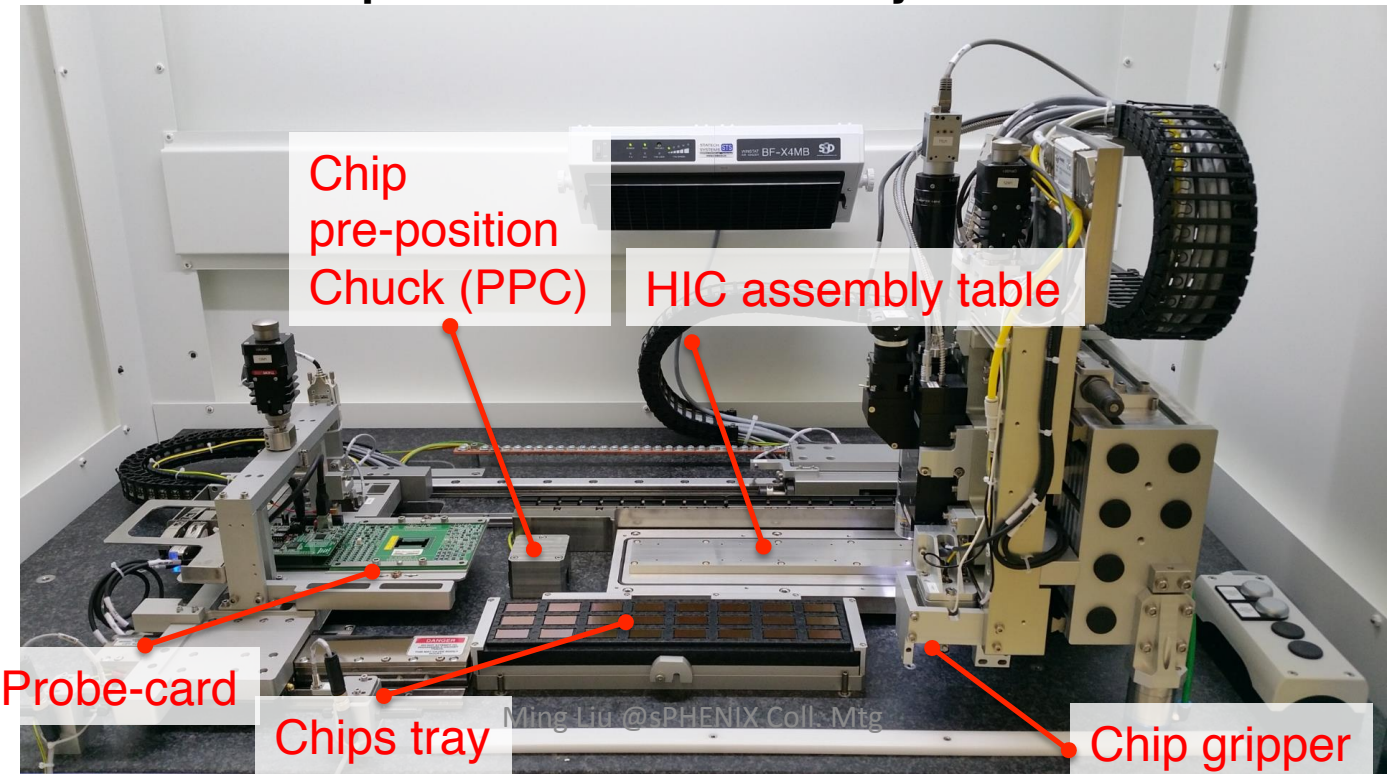


Stave Production & Test @ CERN

From Sanghoon

- Under preparation for massive stave production
  - Overall ALPIDE chip test and HIC/stave production procedure is well established
    Successful ITS Stave production readiness review on Apr/27
  - Optimization of fine configuration is underway
  - Expect to finalize the entire procedure with a new set of ALPIDE chips w/o PIQ which will be ready soon
  - ALPIDE chips with PIQ will be available from mid July

Chip test and HIC assembly machine

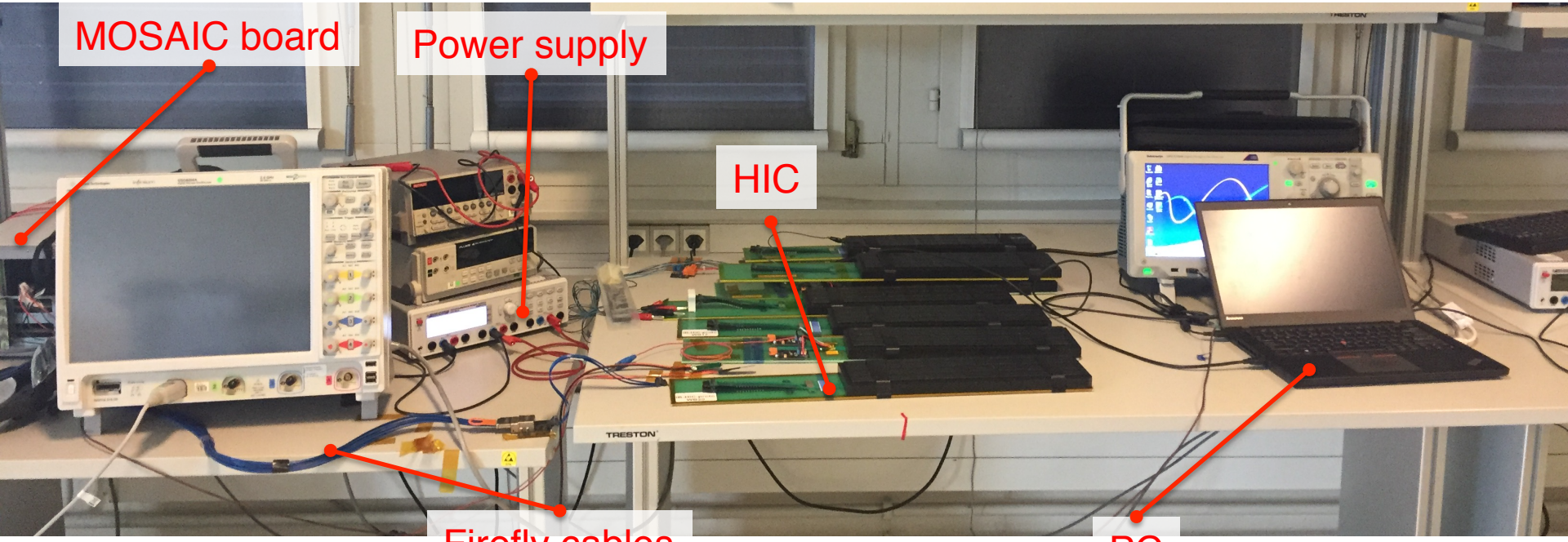


Stave Production & Test @ CERN

- Prototype HICs and staves will be available for LANL R&D soon
  - Multichip readout
  - Mechanical cooling

Sanghoon, Cesar *et. al.* working @CERN
May – Sept. 2016
Czech group – postdocs + Tech @CERN

HIC/Stave test setup @CERN



MVTX Stave Production Plans

- Plan-A
  - CERN production:
    - Assembly and test
  - Time: starting 08/2018, 6-9 months

DOE Budget: FY18

Impact on sPHENIX start date?

CCNU option → plan A?

- Plan-B
  - HICs production @CCNU, Sep. 2018, 2-3 months
  - Stave space frame production @CERN ITS/IB, by 2017
  - Stave assembly: US/LBNL? Or China/CCNU, 4-6 months

Latest News from CERN

1) FPC and chip gluing has ben tested and settled. Production will use 90 microns droplet glue which introduced minimum material budget.

2) Production starts early July. One stave per day. Expect first ALICE/ITS ready January 2018, second detector ready in June 2018.

3) Confirmed MAPS chips and staves frames being produced for MVTX as part of the ALICE contingency

4) Despite the rumors propagated recently, the stave assembly room, machinery and personal will be available after ALICE production. They are also going to make a replica of the entire ITS for NIKA experiment in Dubna during 2019-2020. ATLAS consults on the possibility to use the MAPS technology for their inner tracker upgrade in the future. If they decide for it they will use a completely different facility.

5) LANL is going to send post-docs for 2-3 months stages at CRN to work on the stave characterization.

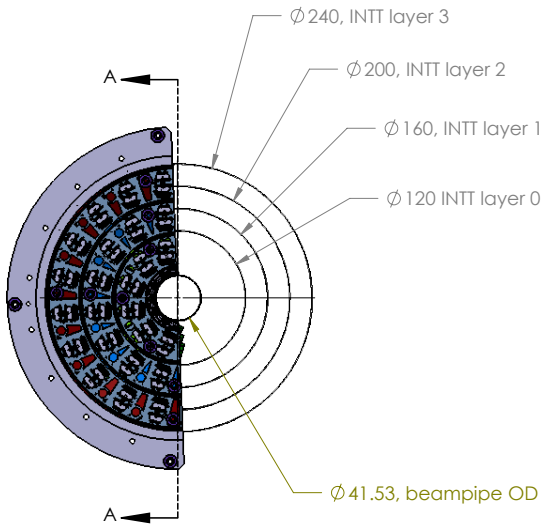
6) FZU Institution from Prague are also sending post-docs and staff to CERN to work on stave characterization.

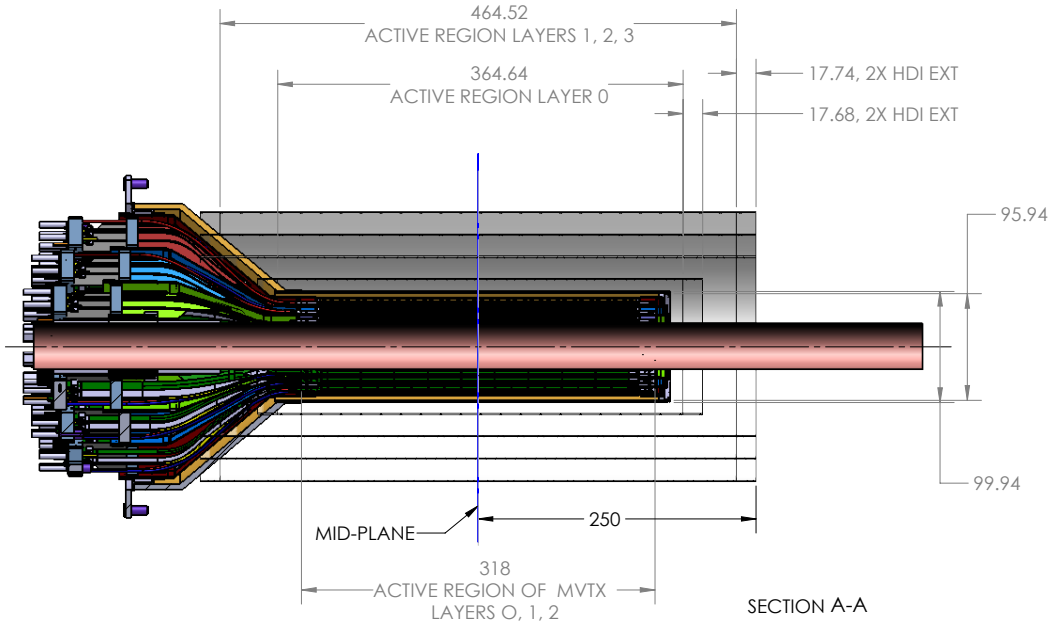
7) We are discussing the possibility for Prague to send a skilled person to work on the construction of the staves. This task requires a skilled person, long training, and to stay at CERN at least six months.

8) Will have at least one stave sent to LANL for R&D in June. We expect to have four (at least partially functioning) staves by the end of September.

MVTX/INTT Integration Issues

From Walt





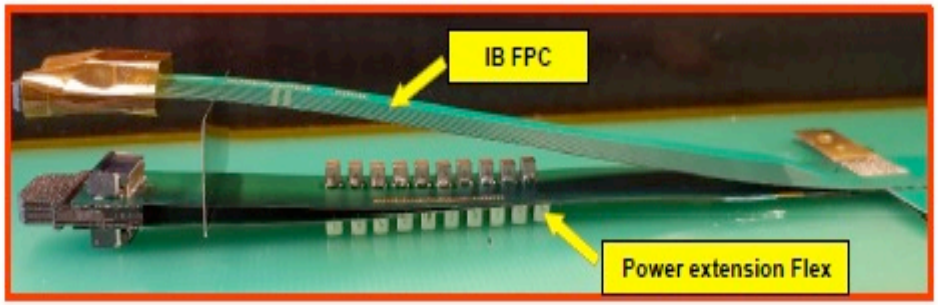
SECTION A-A
SCALE 1 : 4

ALL DIMENSIONS IN MILLIMETERS

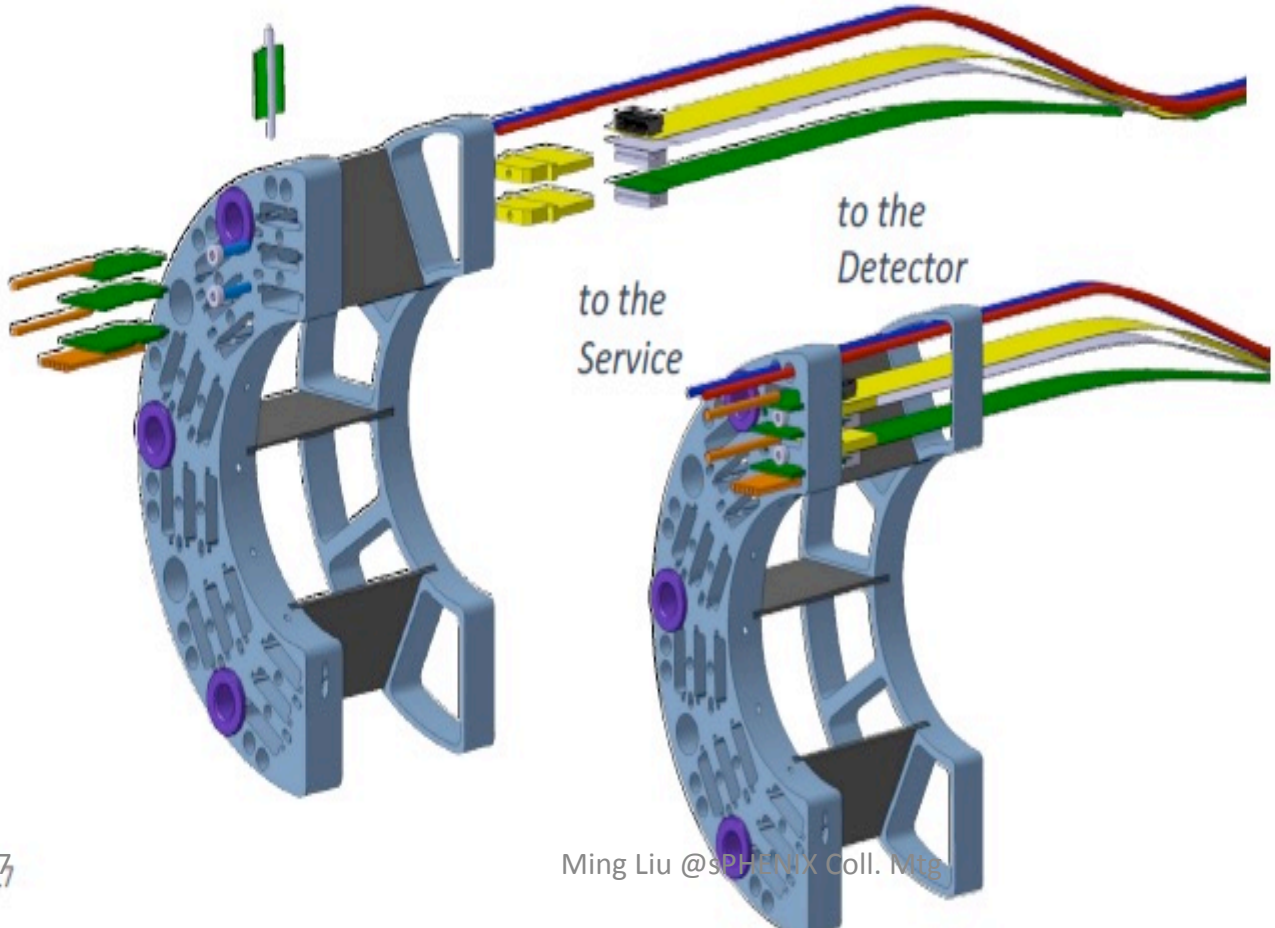
P-25 SUBATOMIC PHYSICS	DIMENSIONS ARE IN INCHES TOLERANCES UNLESS SPECIFIED: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± 0.01 THREE PLACE DECIMAL ± 0.003	NAME / DATE	
Los Alamos NATIONAL LABORATORY EST. 1943	MATERIAL: MIXED	DRAWN: WALT 4/30/2017	INTT & MVTX inner tracker
LOS ALAMOS NATIONAL LABORATORY LOS ALAMOS, NM, 87545	FINISH	CHECKED	SIZE B; DWG. NO.; REV.
	QUANTITY REQUIRED 1	ENG APPR.	SCALE:1: 4; WEIGHT:
		MFG APPR.	SHEET 1 OF 1
		Q.A.	
		COMMENTS:	

FPC Extension for Connection to Electrical Services

Such extensions are equipped with passive components (10x 220 μF capacitors) to stabilize the analogue and digital power supplies, respectively



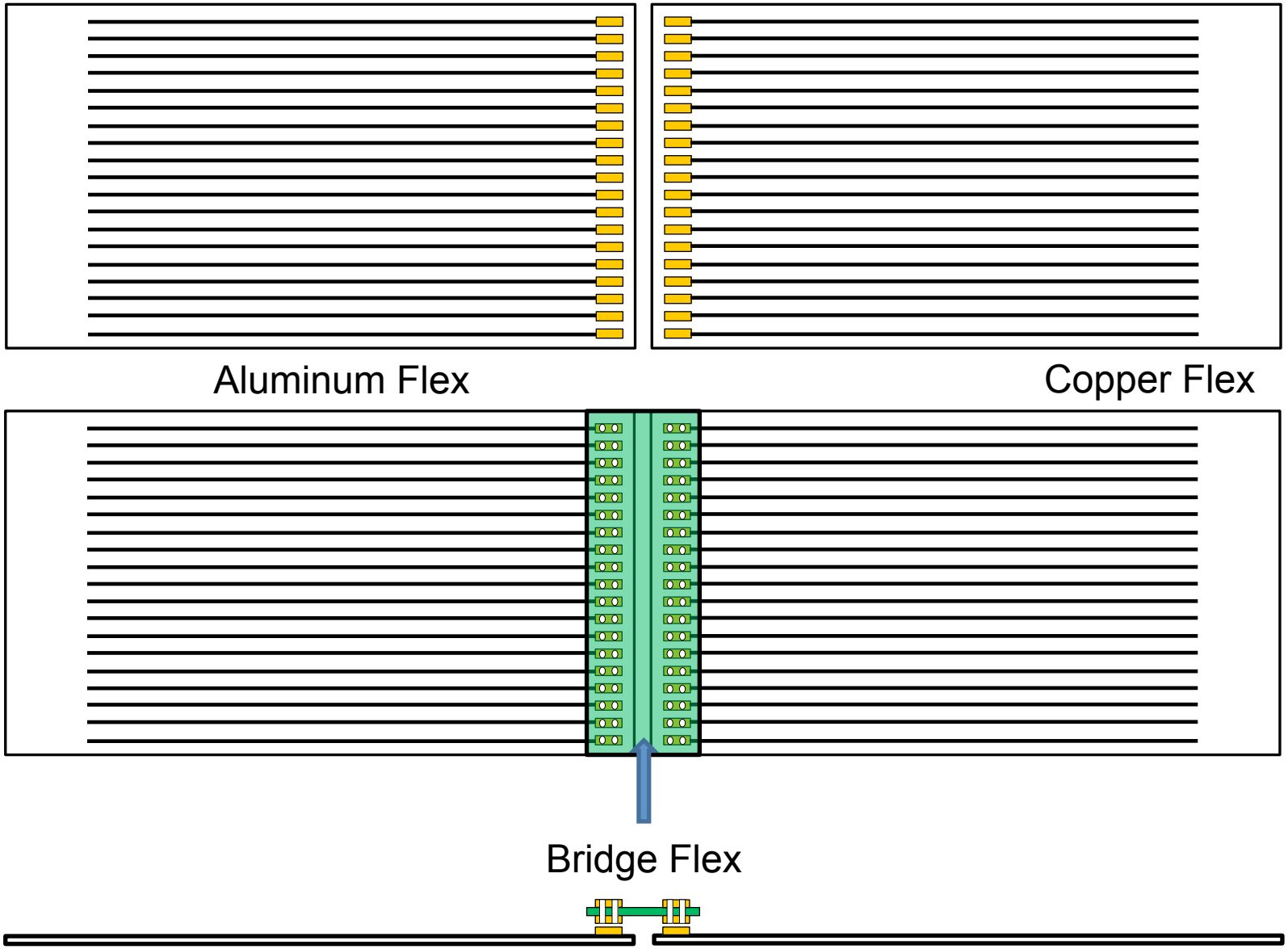
From Walt



This solution allows to implement a "flexible" connection to external service cables with minimized space occupancy

Possible Low Profile Connections

From Sanghoon/Walt



Summary and Outlook

- Exciting physics and great opportunity!

- A lot happened
  - Physics and detector simulations & optimization
  - Good progress with MAPS readout R&D
  - Mechanical integration
  - Some challenges due to delays in ALICE ITS R&

- A lot to do
  - Staves, RU, FELIX/CRU integration
  - PS and controls
  - BNL, DOE Reviews
  - Build and operate the detector
  - and more fun …
  - ***Join us!***

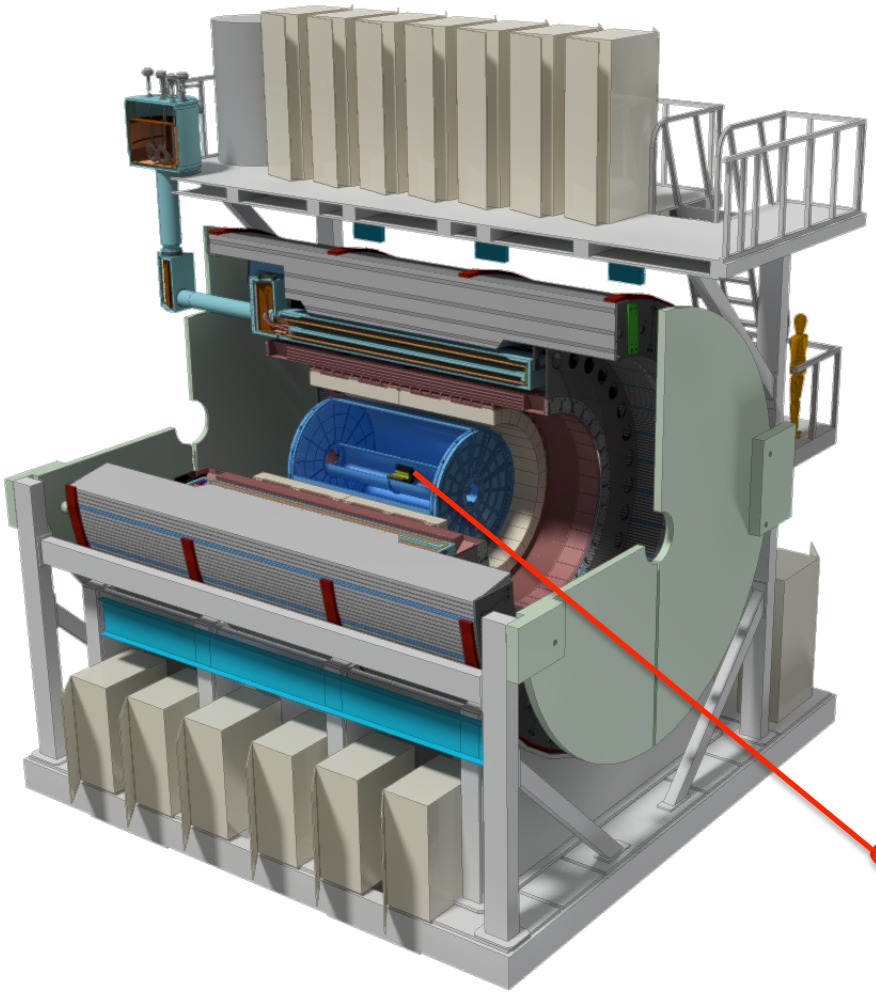
Winter Collaboration Meeting @Santa Fe
A 2.5-day event

- Things to consider:
  - Before or after final exams, or winter breaks
  - Avoid other major meetings/reviews
  - Avoid busy travel seasons
  - Good time for sPHENIX planning etc.

- Possible dates (Fri-Sun?)
  - Nov. 17-19
  - Dec. 1-3
  - Dec. 8-10
  - Jan. 5 -7, 2018

backup

MVTX: WBS 1.12



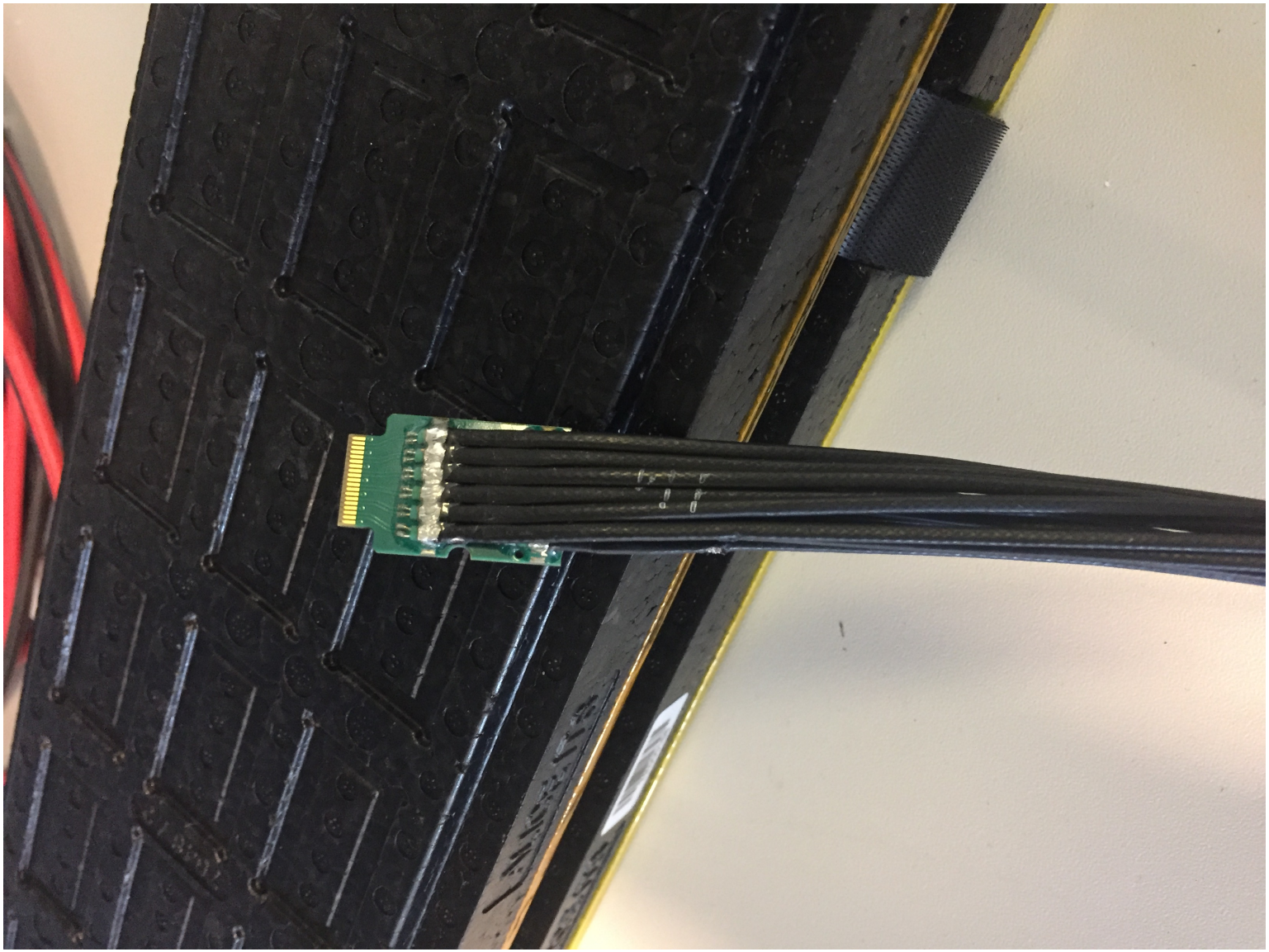
WBS	sPHENIX MIE Project Elements
1.1	Project Management
1.2	Time Projection Chamber
1.3	Electromagnetic Calorimeter
1.4	Hadron Calorimeter
1.5	Calorimeter Electronics
1.6	DAQ-Trigger
1.7	Minimum Bias Trigger Detector

WBS	Infrastructure & Facility Upgrade
1.8	SC-Magnet
1.9	Infrastructure
1.10	Installation-Integration

WBS	Parallel Activities
1.11	Intermediate Silicon Strip Tracker
1.12	Monolithic Active Pixel Sensors

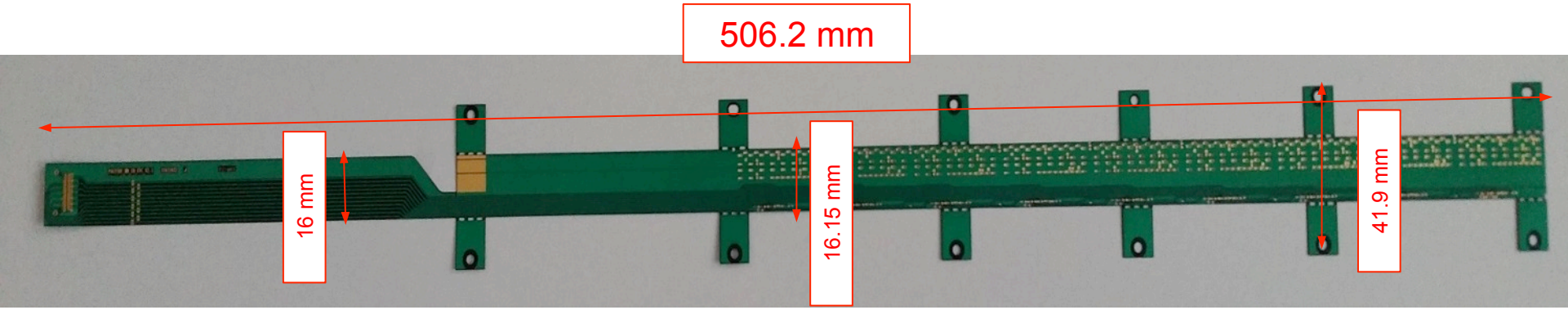
A separate MIE as an upgrade project

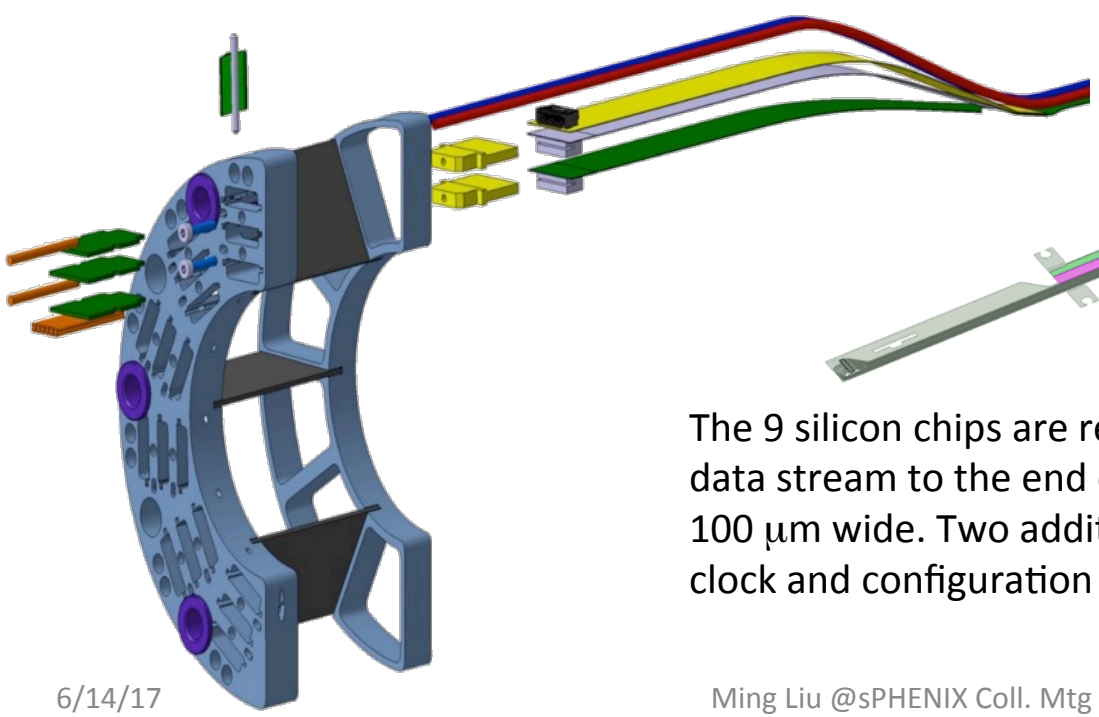
FPC and FireFly Cable Extension

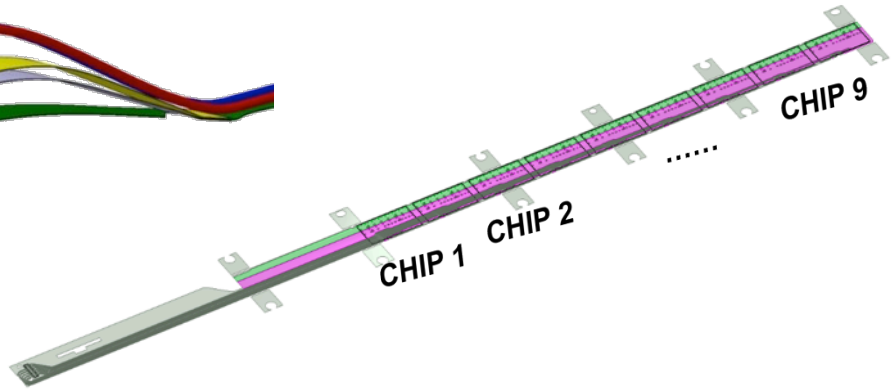


MVTX/INTT Integration

Extend MVTX Service Cables?





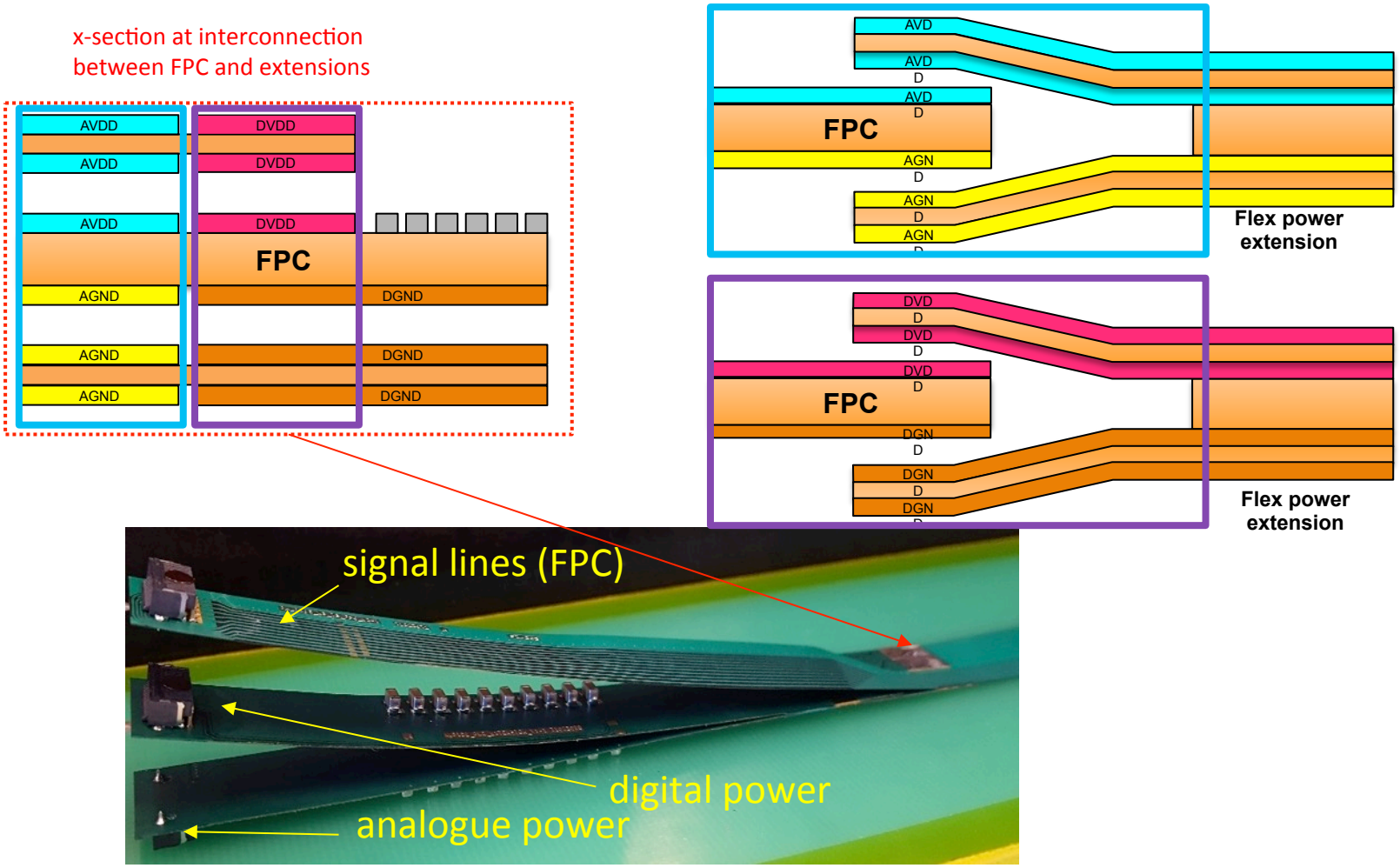


The 9 silicon chips are read out in parallel: each chip sends its data stream to the end of Stave by a dedicated differential pair, 100 μm wide. Two additional differential pairs distribute the clock and configuration signals.

FPC Extension for Connection to Electrical Services

Antonello Di Mauro, Stave PRR 4/27/2017

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



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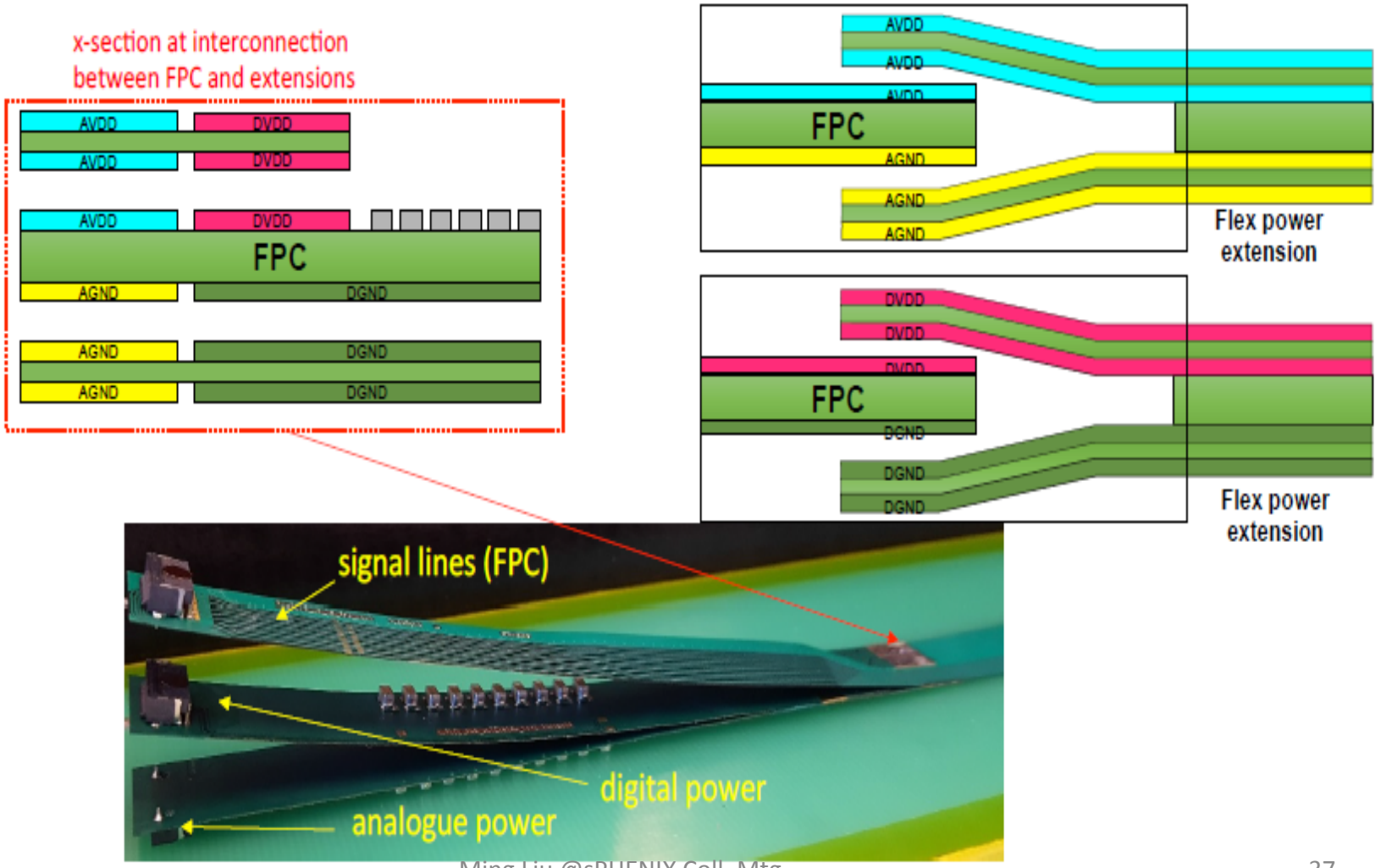
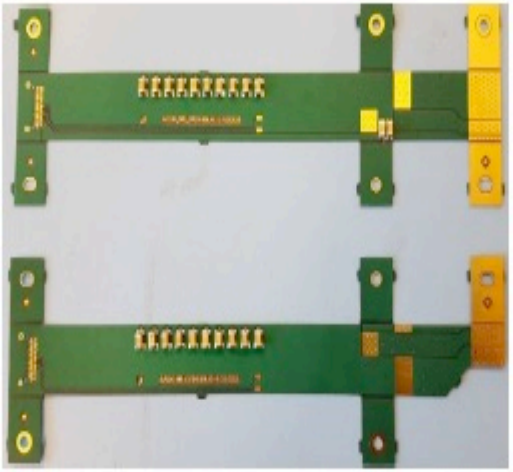
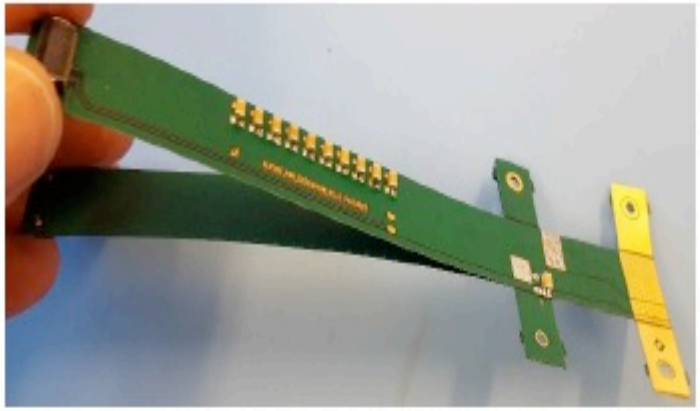


FPC Extension for Connection to Electrical Services

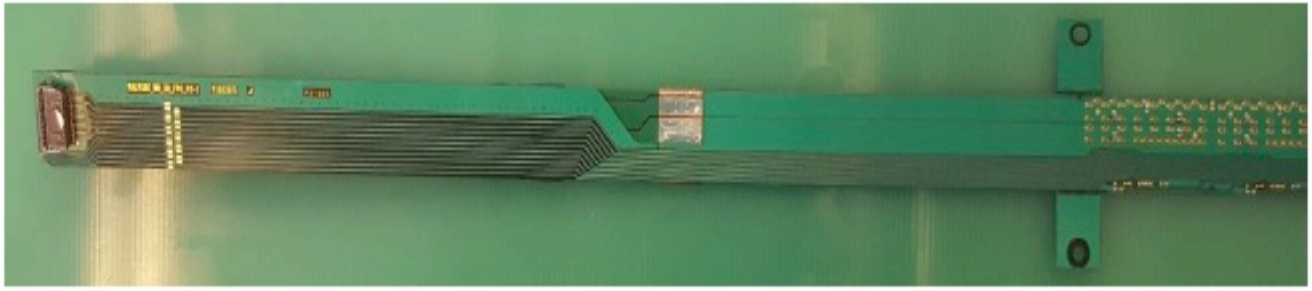


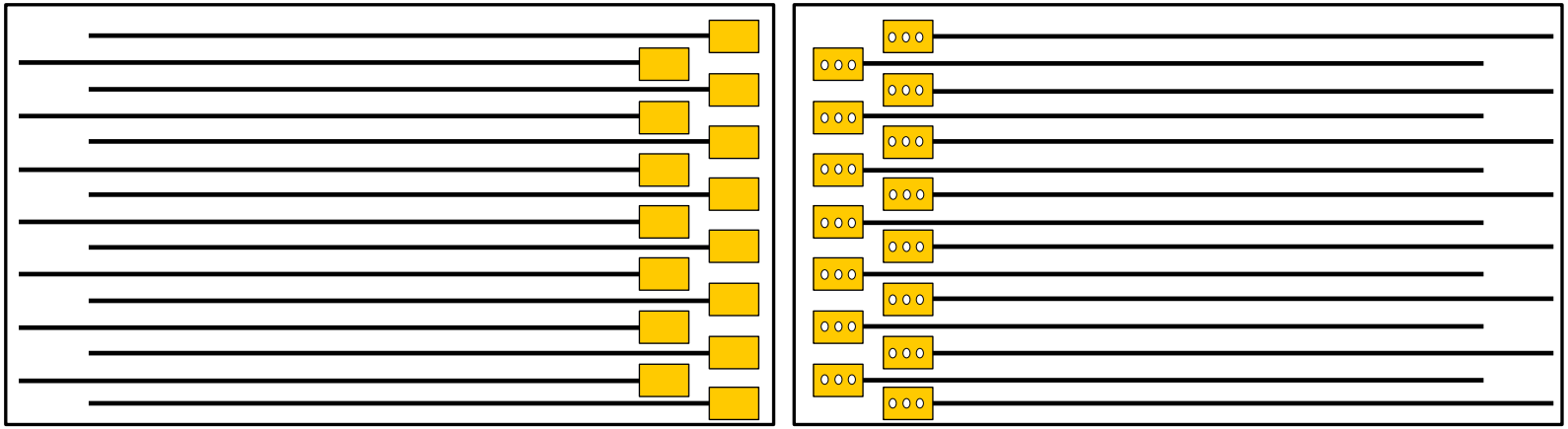
2 Cu layer flex, PI : 50 µm, Cu : 35 µm, Solder mask : 20 µm



The 2 flexes are glued together, in the middle to have a 4 layers flex.

The PWR_extension is connected to the FPC by iron soldering.





Aluminum Flex

Copper Flex

HICs Assembly Lab @CCNU

space ~ 70m^2 (1K clean room); 20m^2 (10K clean room, 2.9m head room)

- Chip and FPC gluing
- Gluing FPC/MAPS
- Chip mounting
- Wire Bonding
- Electrical circuit testing
- Storage

Machine shop: (Sun, Daming, Tech.)
- CNC etc.
- Simple mechanical structures

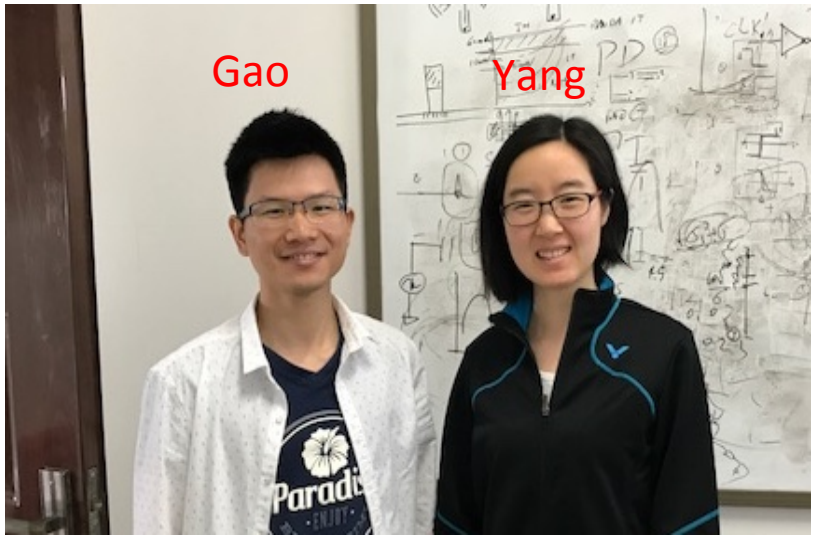
Not Doing at present:
- Stave assembly
- No carbon structures

CCNU Plan – Cont.

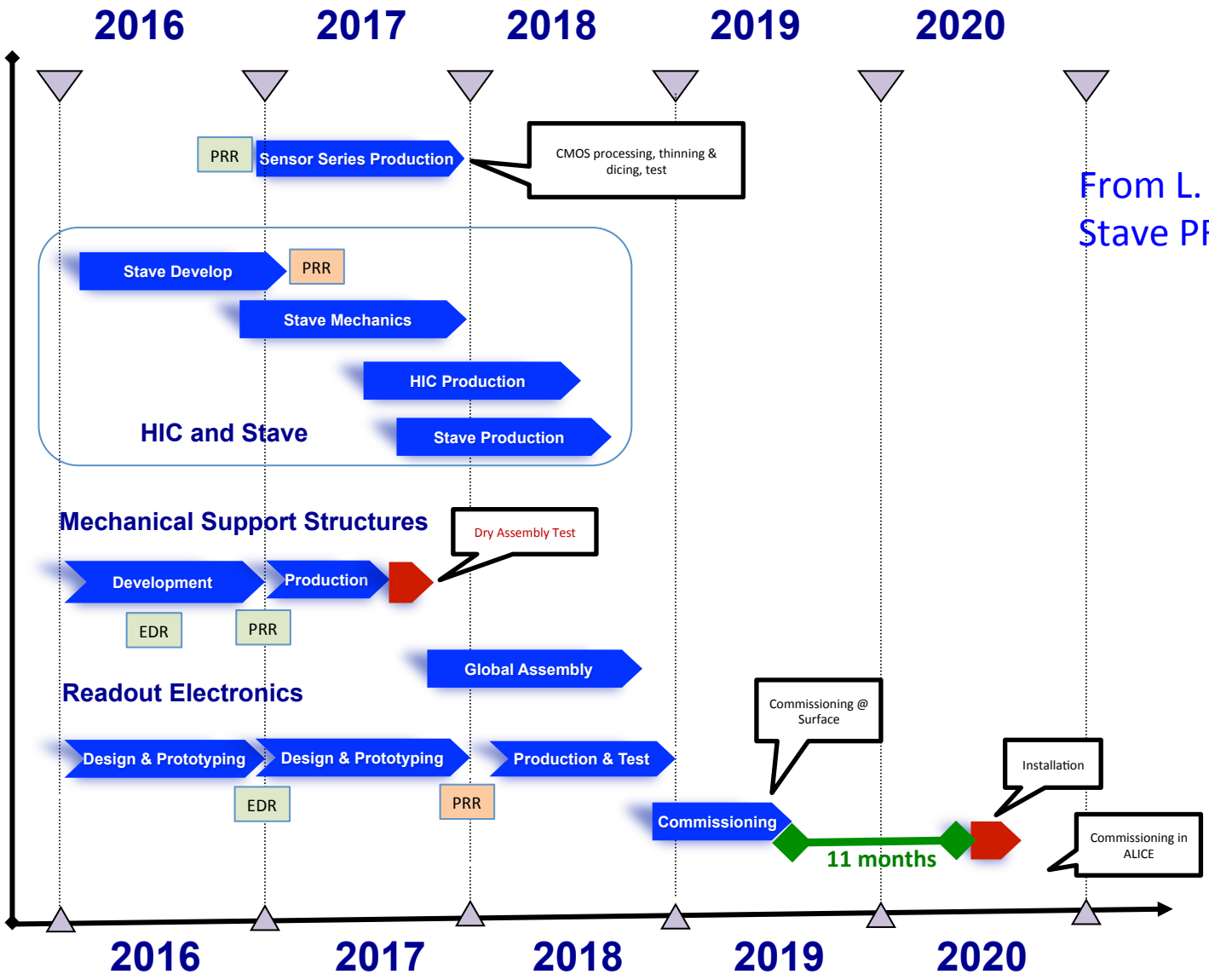
- Experts and Designers of ALICE MAPS/ALPIDE on-chip electronics
  - Analogy circuit – Dr. Chaosong Gao
  - Digital circuit – Dr. Ping Yang
  - They will help us!

- PLAC – Pixel Lab At CCNU
  - Also interested in mechanical system integration
  - Plan to hire a full time engineer to work on sPHENIX integration effort
    - Visit LANL 6-12 months, work on preliminary conceptual design for the MVTX/INTT/TPC

- Physics simulation and analysis
  - Many students



Overall ITS Planning (Simplified Global View)



From L. Musa, 4/27/2017
Stave PRR Presentation

Project Review Milestones

From L. Musa, 4/27/2017

① Pixel Sensor Chip - EDR (Oct' 15)
② Stave - EDR (May' 16)
③ Detector Barrel Mechanics - EDR (Jul '16)
④ Cooling – EDR (Jul '16)
⑤ Pixel Sensor Chip - PRR (Nov '16)
⑥ Detector Barrel Mechanics - PRR (Dec '16)
⑦ Service Barrel Mechanics - EDR (Dec '16): done
⑧ Cooling – PRR (Dec '16): done
⑨ Readout Electronics – EDR (Jan '17): done
⑩ Stave - PRR (Apr '17)
11 Service Barrel Mechanics – PRR (May '17)
12 Readout Electronics – PRR (Dec '17)

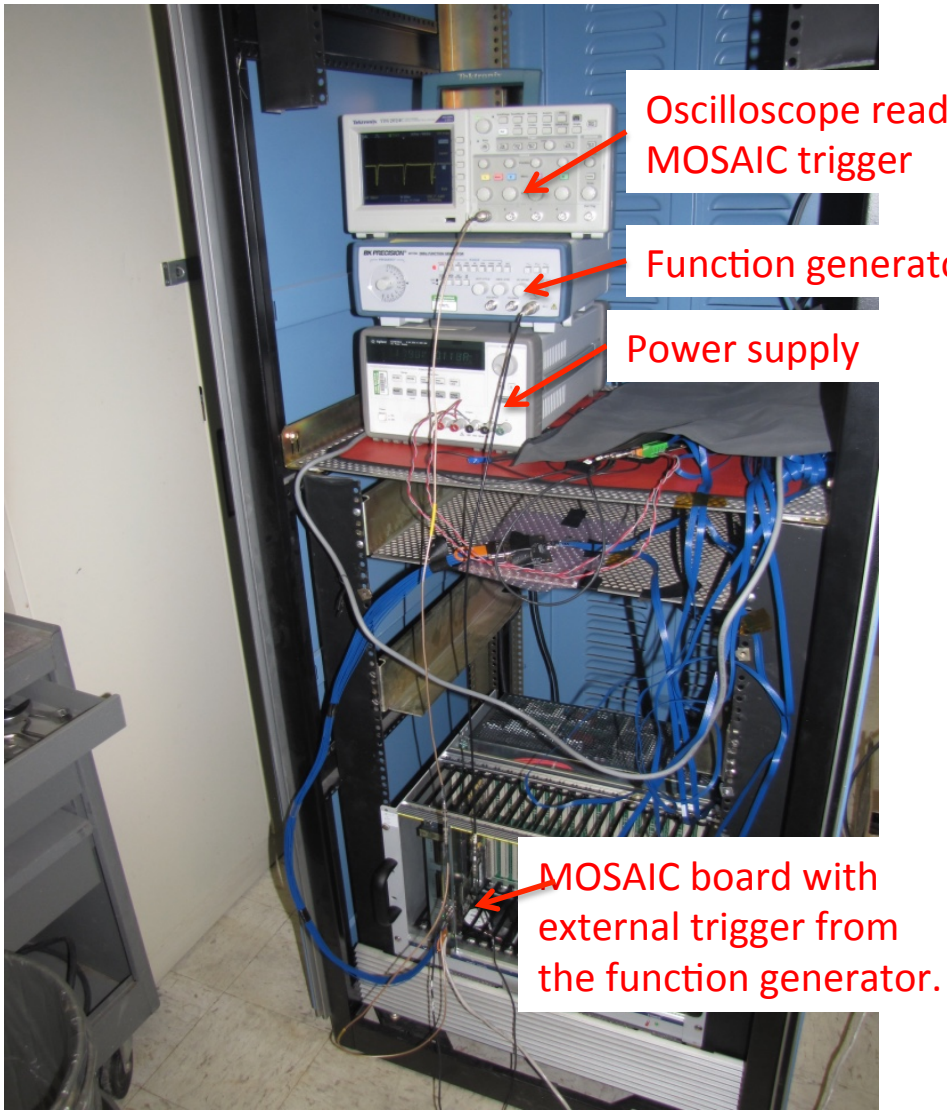
Stave Production Readiness Review:
4/27/2017

- Stave production starts ~May/June;
- 1st set of IB by Jan 2018;
- 2nd set of IB by July 2018
- LANL people + others/MVTX work on stave production from May 2017 at CERN, prototype available soon at LANL

- Fully working staves for R&D available ~Jan 2018;
- Near final readout RU/CRU: ~12/2017

External trigger setting with a pulse generator

- Use Chip 4 for test.
- Use a pulse generator as the external trigger source. Now use 2MHz square pulse.
- Readout the FE trigger output of the MOSAIC board and check in the oscilloscope.
- Need to tune the external trigger to be in the phase locker.



Test under internal trigger (40MHz)

From Xuan

- Readout speed 600 Mb/s and 50 injections.
- Scan the threshold per pixel and the average value is 394.33±41.79 (e).