sPHENIX MAPS Inner Tracker

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Inputs from Mike McCumber, Cesar da Silva, Pat McGaughey, Dave Lee, Jin Huang, Xuan Li, Marks Prokop, Walt Sondheim, Sanghoon Lim, Hubert van Hecke, Haiwang Yu, Ed O'Brien, John Haggerty, Leo Greiner, Luciano Musa … et al

Outline

- Motivation
- MAPS Inner Tracker Scope
- MAPS Project Status
- MAPS R&D at CERN and LANL

Full MAPS MIE proposal writing:

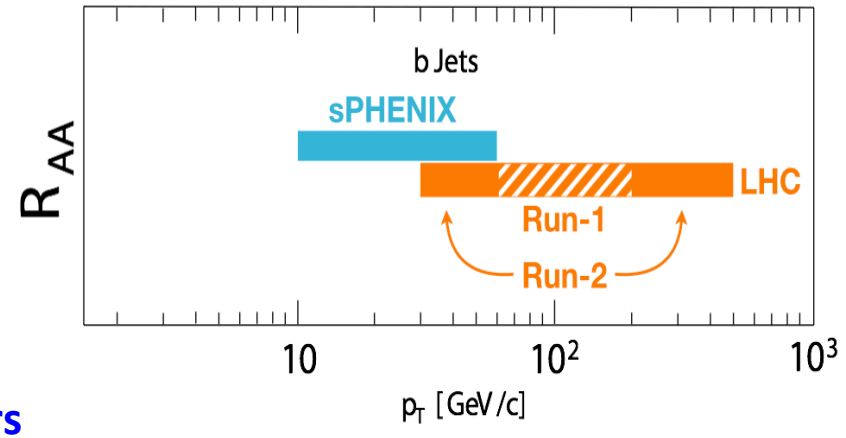
Santa Fe HF-Jet/MAPS Workfest 1/5-7, 2017

https://indico.bnl.gov/conferenceDisplay.py?ovw=True&confId=2641

Exciting Science: Physics of the 3rd Pillar

- sPHENIX is the next flagship heavy ion physics experiment in US
  - Jets
  - Upsilons
  - B-jets

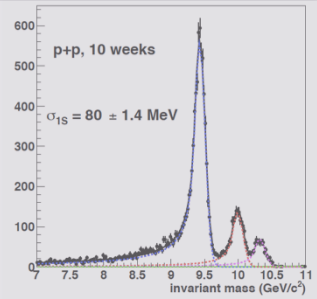
Cannot be done at the LHC for lack of low pT reach and huge backgrounds



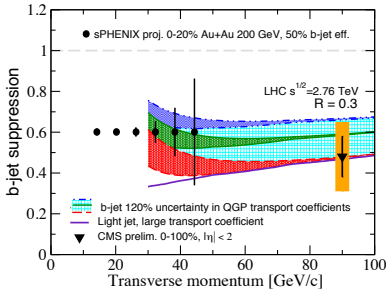
sPHENIX Three Physics Pillars

Jets

Upsilons



B-Jets Physics

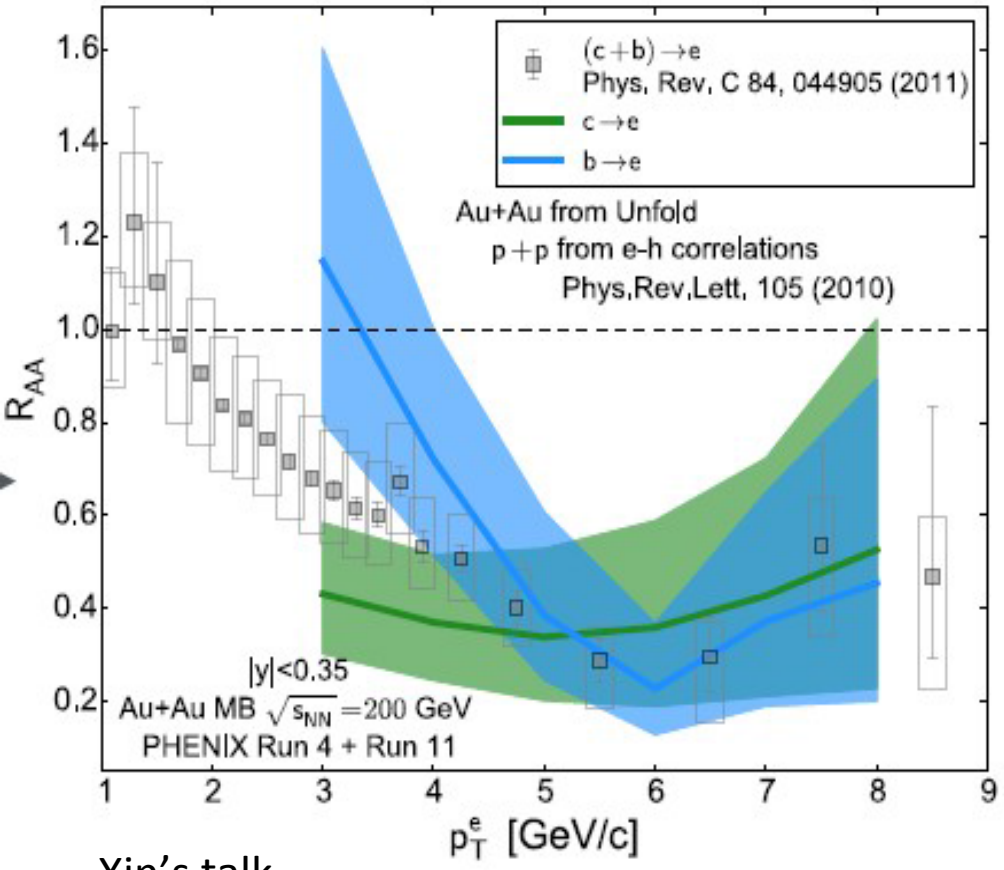


Jin's talk

Heavy Quark Energy Loss @RHIC

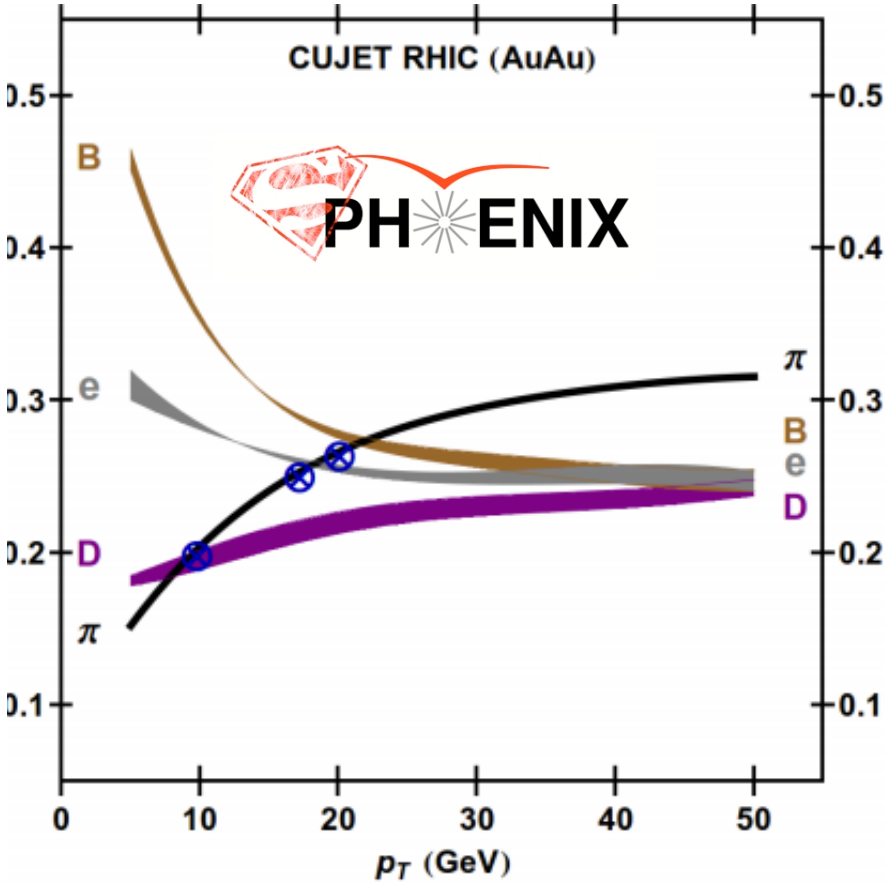
"Jet flavor tomography"

PHENIX PRC 93 (2016) 034904



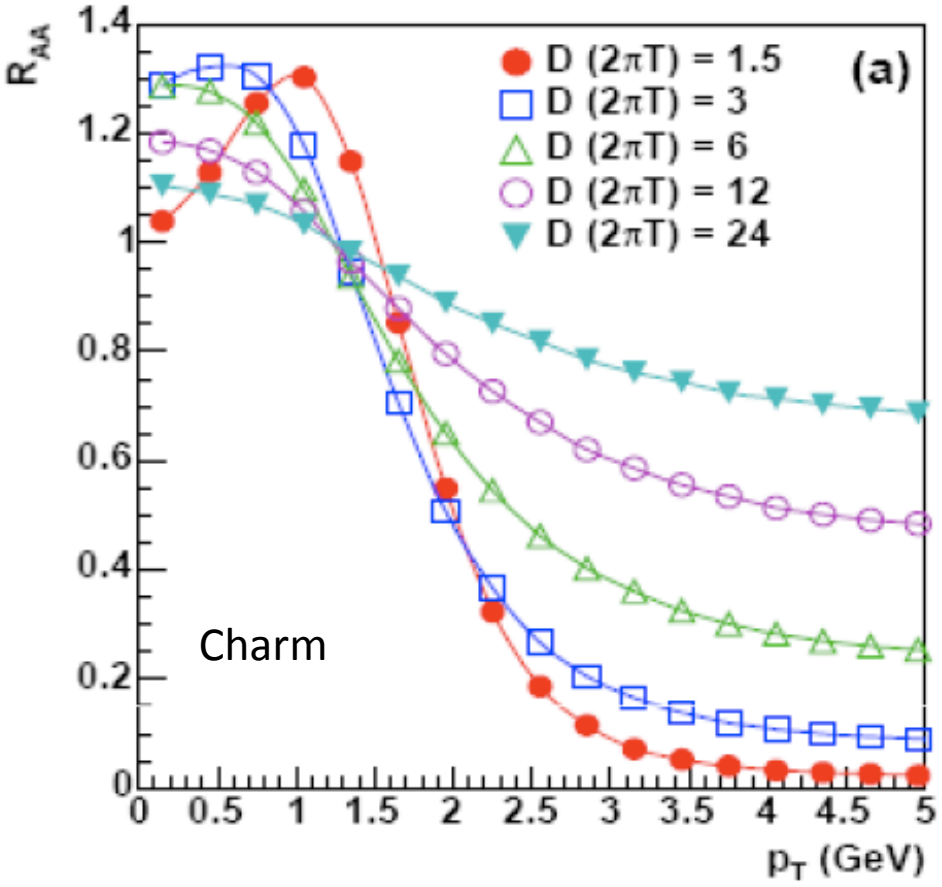
Xin's talk

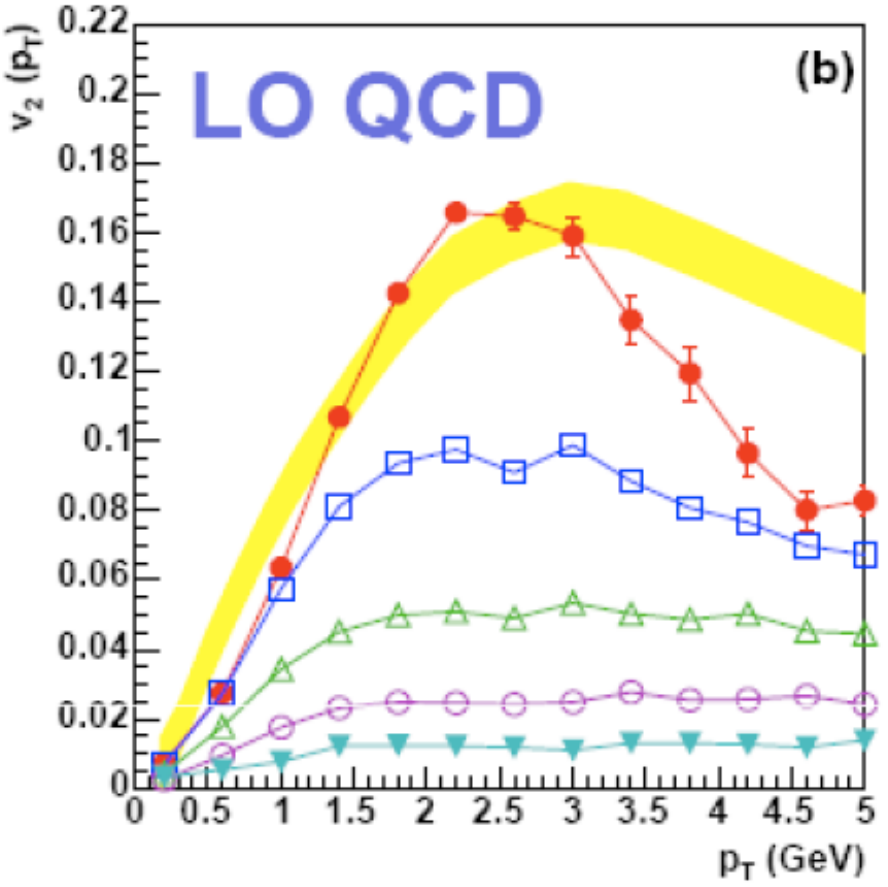
Buzzatti et al., PRL 108 (2012) 022301



Heavy Quarks: Sensitive to Medium Properties

Moore & Teaney, PRC 71 (2005) 064904





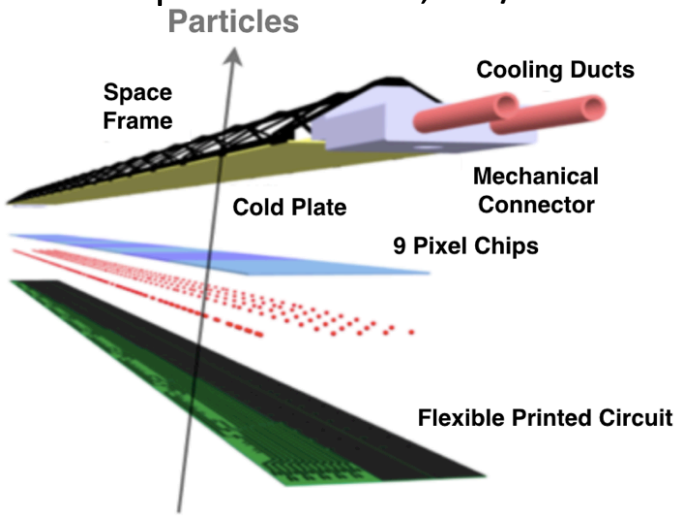
Xin's talk

Monolithic-Active-Pixel-Sensor MAPS

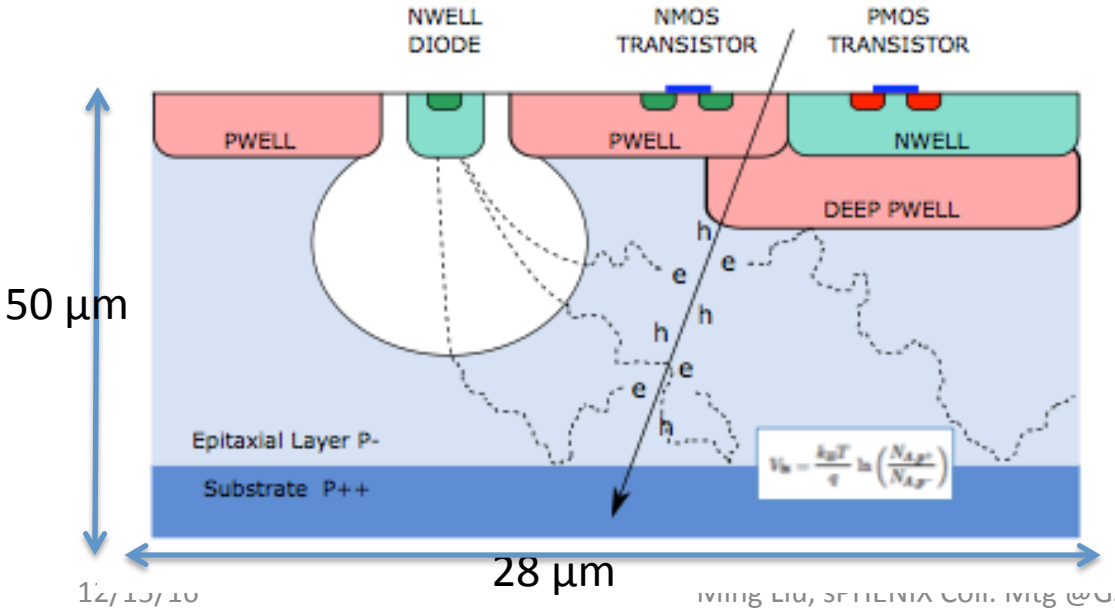
A State of the Art Tracker

- Advantages of MAPS:
  - Very fine pitch (28x28 µm)
  - High efficiency (>99%) and low noise (<10^{-6})
  - High speed, 2~4 µS
  - Ultra-thin/low mass, 50µm (~0.3% X_0)
  - On-pixel digitization, low power dissipation
  - 15+ years of R&D at CERN for ALICE upgrade

A 9-chip MAPS stave, ITS/IB



An ideal detector for QGP b-jet physics!



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: $N_A \sim 10^{16}$

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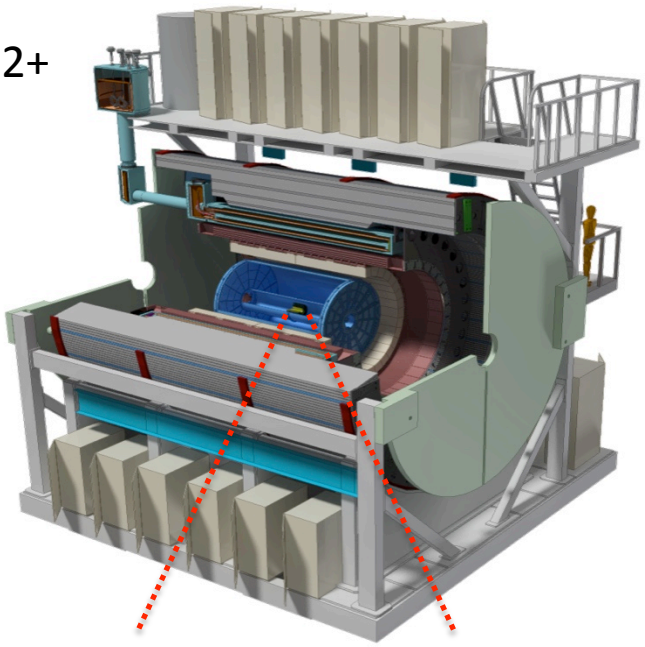
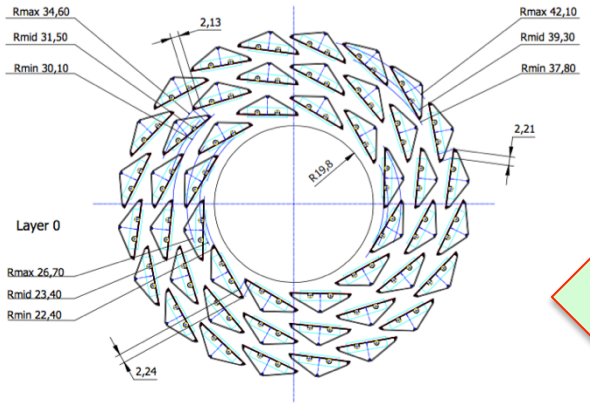
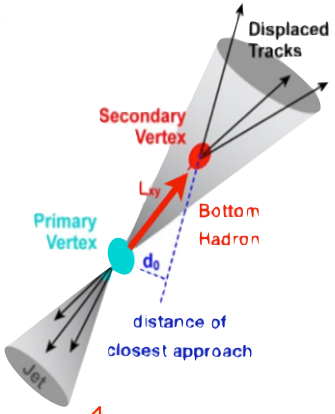
sPHENIX MAPS Inner Tracker

2022+



sPHENIX Inner Tracking

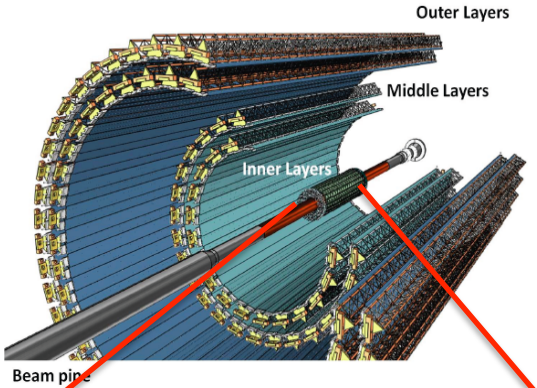


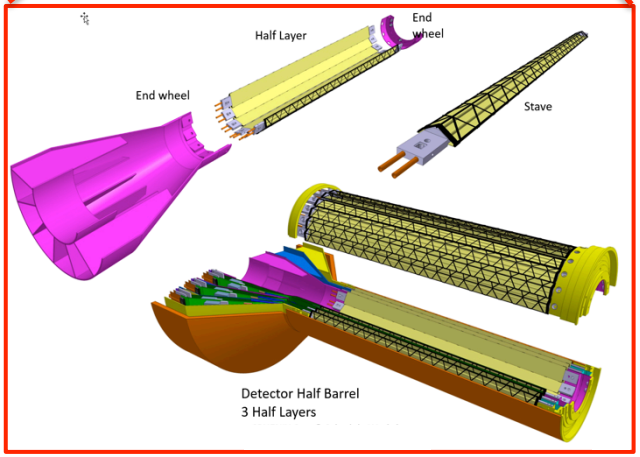


Key issues:
- Readout
- Mechanics

"Adopt" ALICE/ITS
Mini. risk,
Max. physics

ALICE ITS Upgrade (2021+);
Inner Tracker System

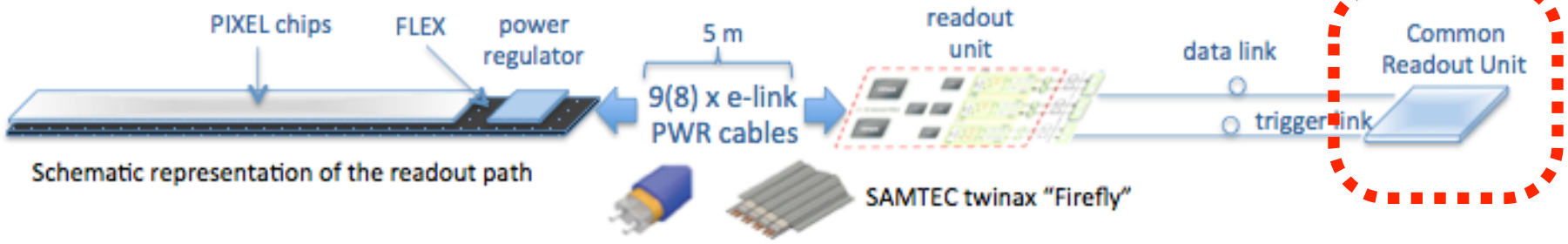




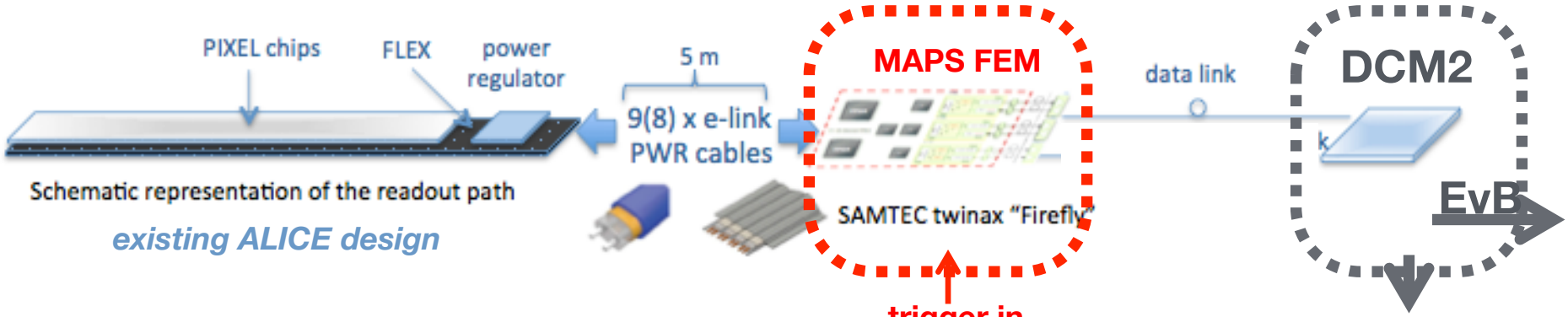
MAPS-sPHENIX Electronics Integration

ALICE readout path

Plan A: reprogram



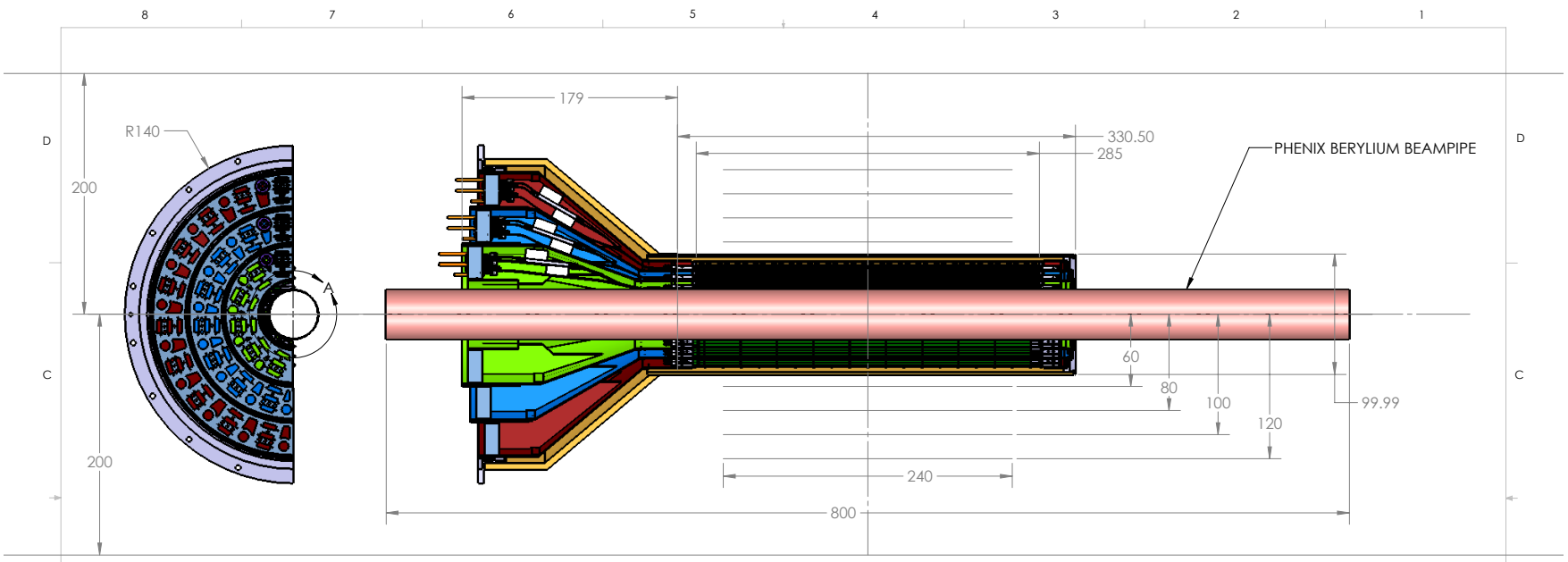
Plan B: sPHENIX readout path (held as contingency)



New development:

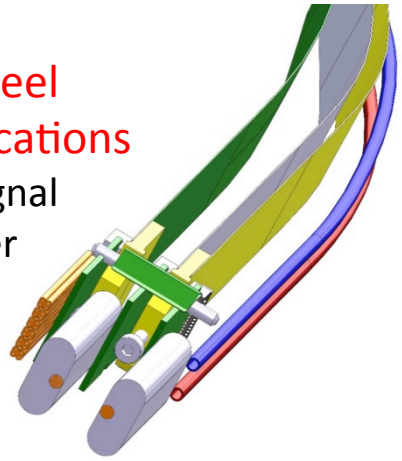
- Joint TPC & MAPS readout R&D
- ATLAS FELIX Readout Unit vs ALICE/CRU?

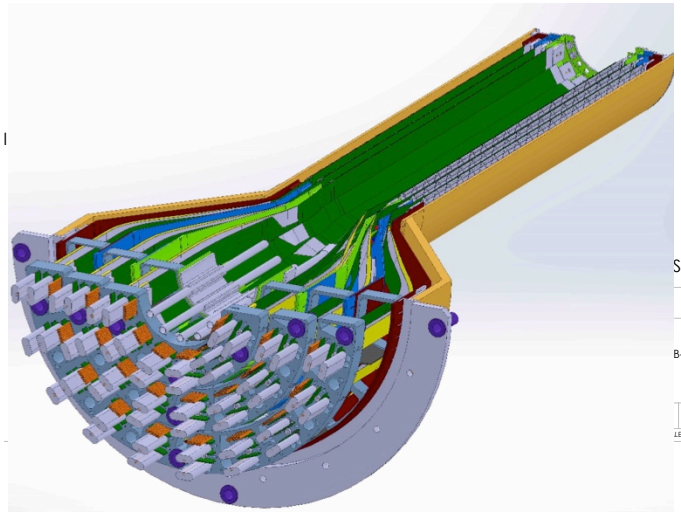
MAPS-sPHENIX Mechanical Integration



Service End Wheel
Possible modifications

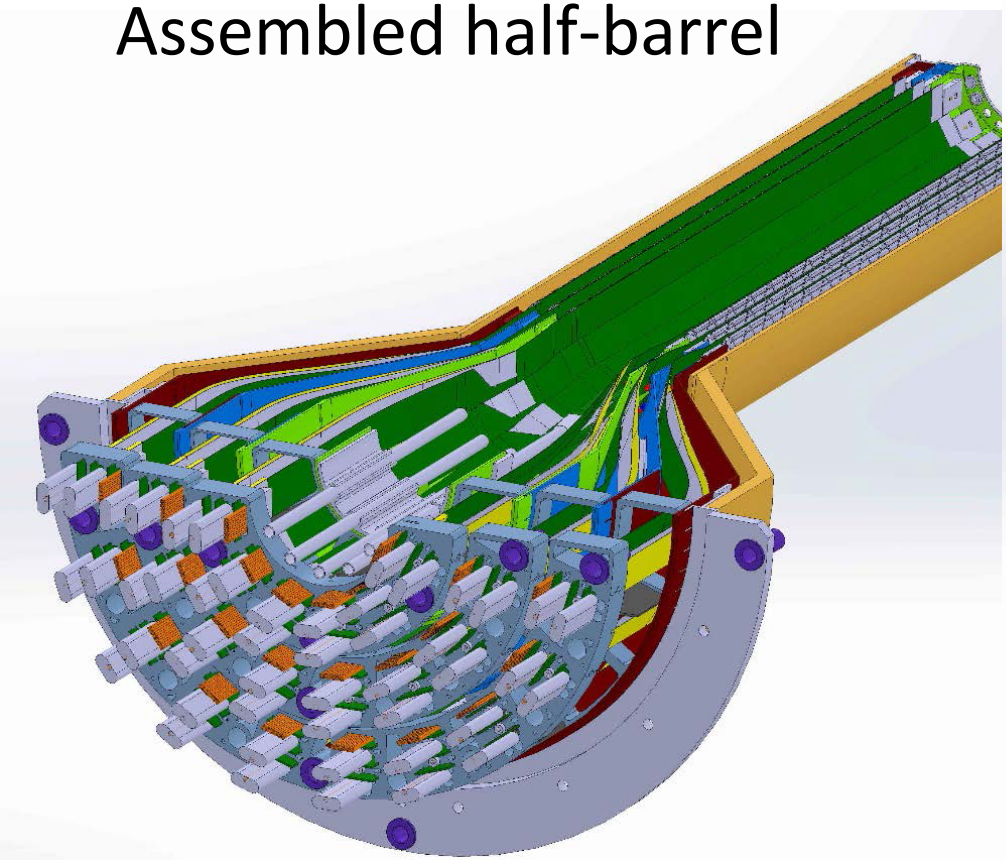
- High speed signal
- Analogy power
- Digital power
- Cooling

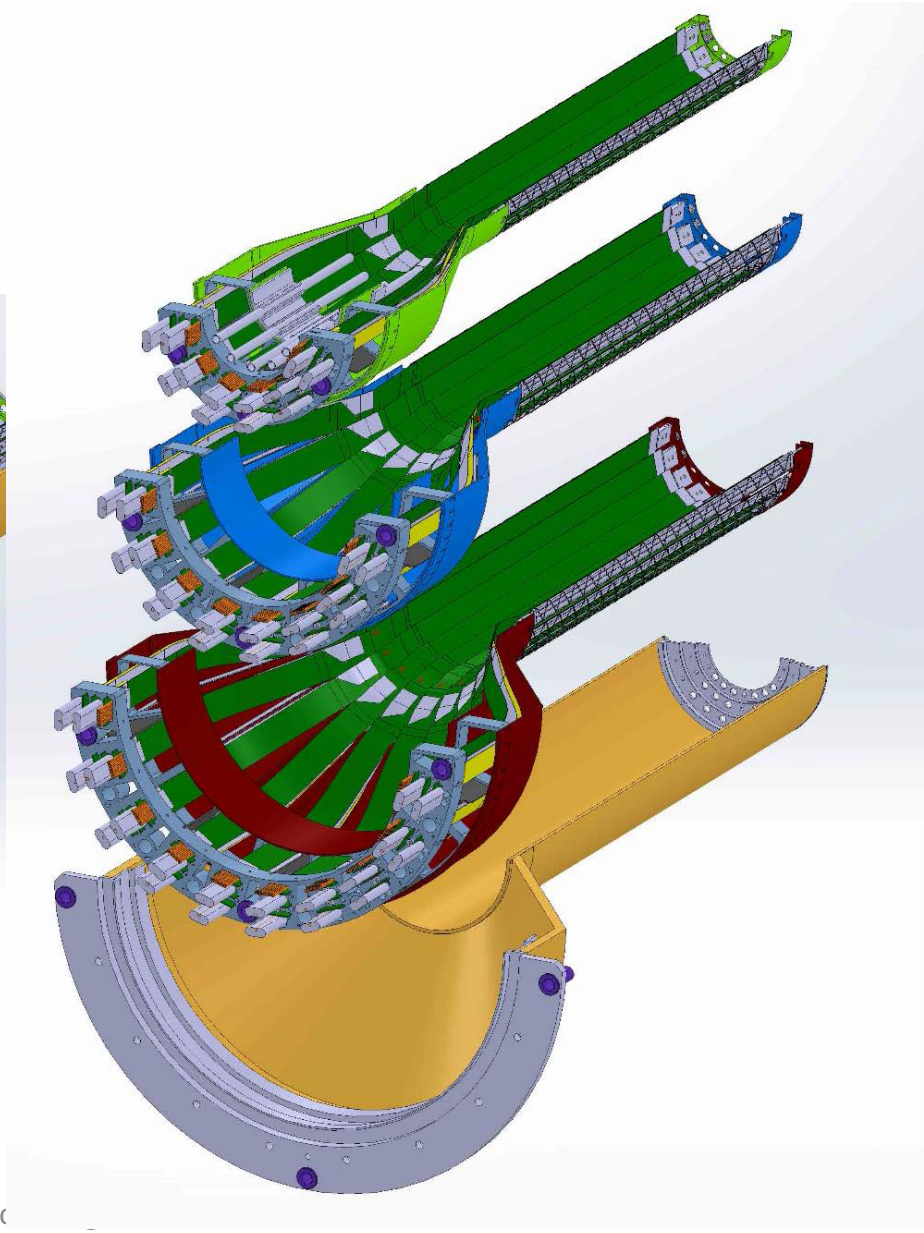




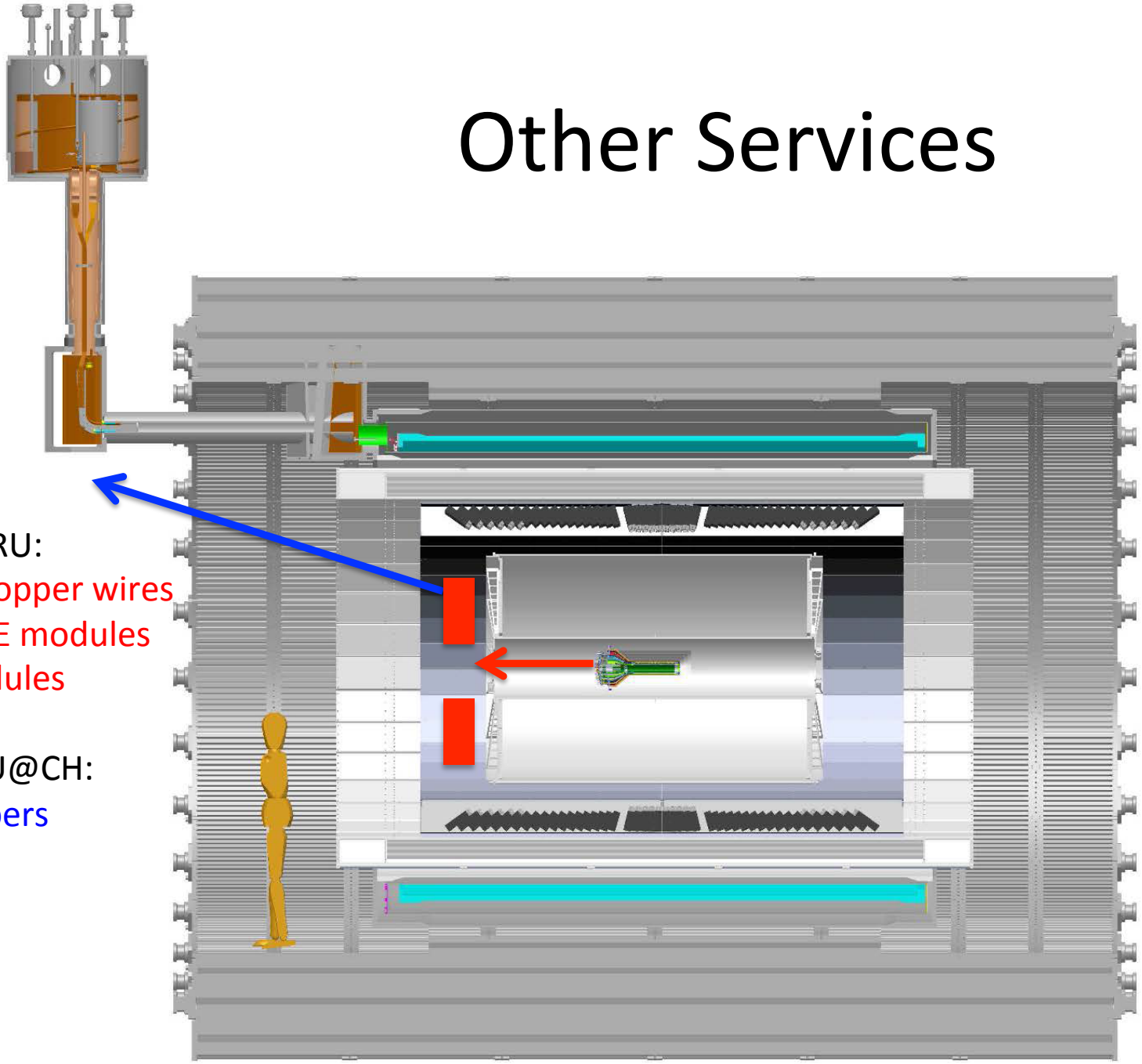
MAPS Inner Tracker Mechanic Frames

Assembled half-barrel





Other Services



MAPS->RU:
- “5m” copper wires
- 6U VME modules
- 48 modules

RU->CRU@CH:
30+m fibers

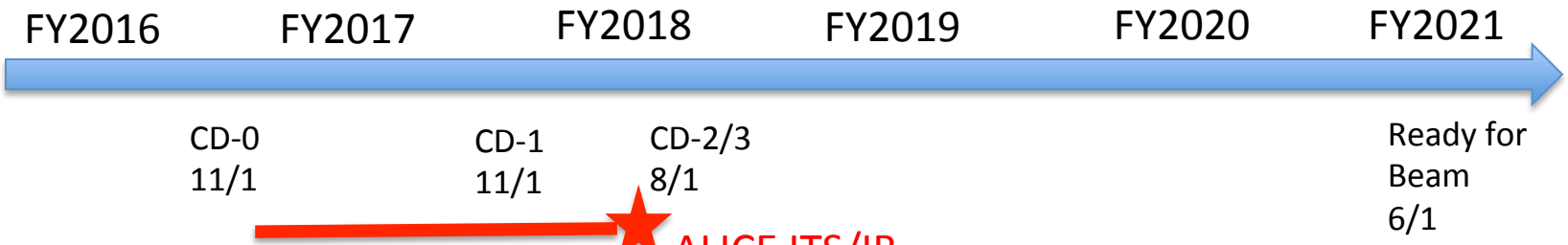
Scope of the MAPS Project

- MAPS & Electronics
  - MAPS Detectors
    - "MoU" to build 68 ITS MAPS staves
    - No modification
  - Readout Electronics
    - Use ALICE/ITS, RU + CRU
    - Modify/reprogram CRU for sPHENIX
      - Plan-B: build a custom board to convert ALICE/ITS into sPHENIX DAQ format
    - R&D by LANL LDRD
  - Production
    - Extend ALICE/ITS MAPS stave production
    - Train sPHENIX personnel for assembly and testing staves at CERN
    - Reproduce additional ALICE RU+CRU for sPHENIX
  - Ancillary systems, copy ALICE
    - LV, cables, crates, racks etc.
    - Slow control, safety and monitoring
- Mechanics & Cooling
  - No/(minor) changes to ALICE/ITS inner tracker mechanical structures
    - End Wheels
    - Cylindrical structure shells
    - Detector half barrels
    - Service half barrels
    - Detector and Service half barrels
    - Half support structures
  - 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

A new MIE to fund the full MAPS detector, ~$5M

From 09/2016 review

Project Tasks and Timeline



Key R&D

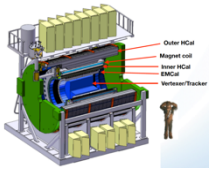
Readout R&D
Mech. design
@LANL/ALICE

Mech. Integr.
& Prototype
@MIT/LBNL

A schedule driven project!

Production

MAPS Prod. & QA @ALICE → Stave prod.&Test @CERN; RUs Prod. @US → Detector. Assembly & Test @BNL → Det. Install. @BNL



+2% +50%

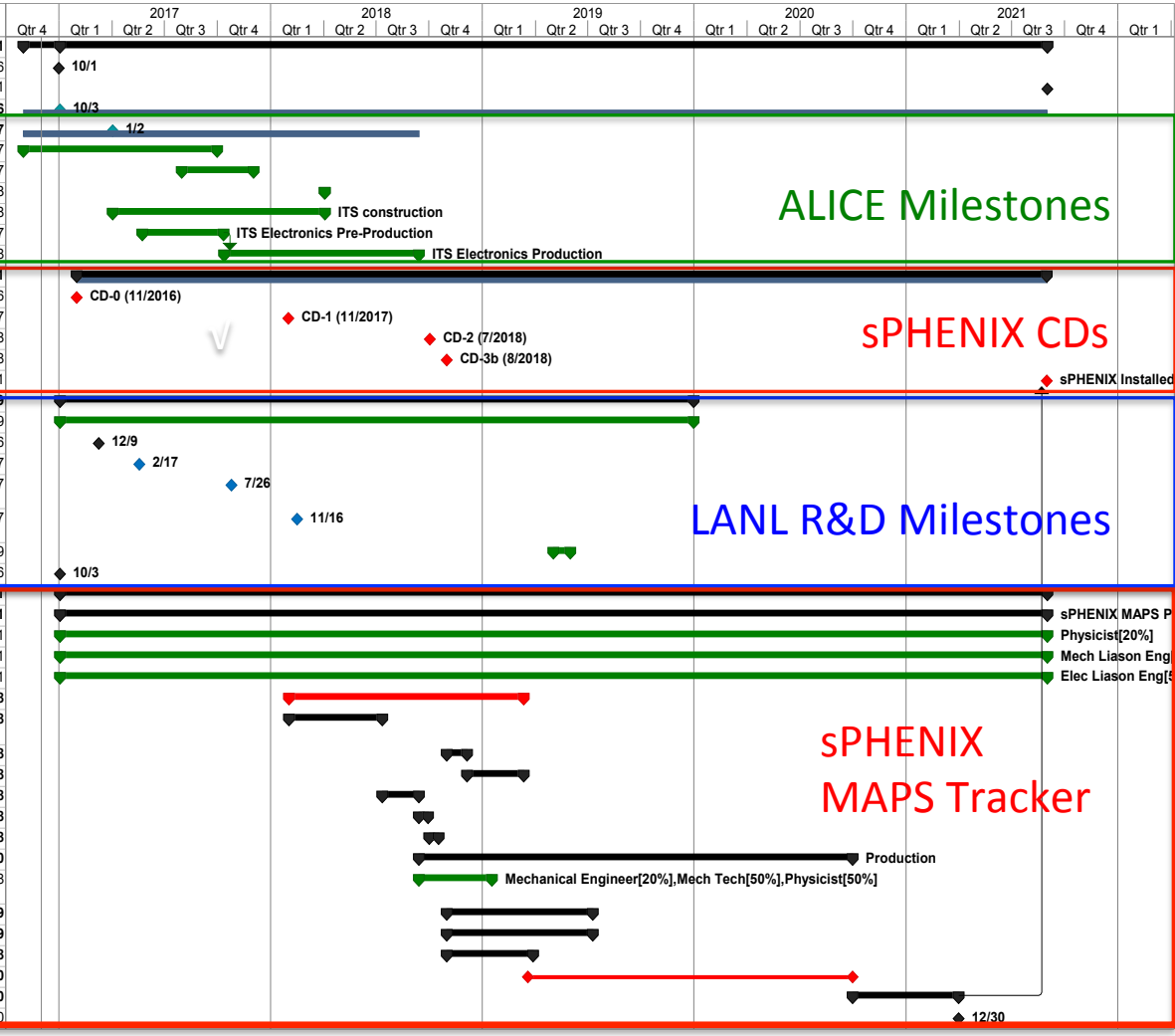
"MoU" w/ ALICE/ITS: 11/2016
- Produce MAPS chips for sPHENIX as part of ALICE production!
- Full staves, space frames and RUs production cost & schedule → **MAPS MIE**

Key Schedule: ALICE and sPHENIX

From 09/2016 review

Thu 9/1/16

ID	WBS	Task Name	Duration	Start	Finish
1	1	**MAPS Inner Barrel**	**1217 days**	**Mon 10/3/16**	**Tue 6/1/21**
2	1.1	MAPS Inner Barrel Starts	0 days	Sat 10/1/16	Sat 10/1/16
3	1.2	MAPS Inner Barrel Ends	0 days	Tue 6/1/21	Tue 6/1/21
4	1.3	**Milestones & Key Tasks**	**0 days**	**Mon 10/3/16**	**Mon 10/3/16**
5	1.3.1	**ALICE ITS Key Tasks**	**0 days**	**Mon 1/2/17**	**Mon 1/2/17**
6	1.3.1.1	ALICE MAPS Production (7/17)	240 days?	Mon 8/1/16	Fri 6/30/17
7	1.3.1.2	ALICE ITS IB FPC Production (9/17)	90 days	Mon 5/1/17	Fri 9/1/17
8	1.3.1.3	ALICE ITS IB Stave Production (1/18)	1 day?	Tue 1/2/18	Tue 1/2/18
9	1.3.1.4	ALICE ITS IB Stave Assembly (3/18)	262 days	Mon 1/2/17	Tue 1/2/18
10	1.3.1.5	ALICE ITS Electronics Pre-Production (7/17)	100 days	Wed 2/22/17	Tue 7/11/17
11	1.3.1.6	ALICE ITS Electronics Production (6/18)	240 days	Thu 7/13/17	Wed 6/13/18
12	1.3.2	**sPHENIX Milestones**	**1195 days**	**Tue 11/1/16**	**Tue 6/1/21**
13	1.3.2.1	sPHENIX Technical Design CD-0	0 days	Tue 11/1/16	Tue 11/1/16
14	1.3.2.2	sPHENIX Technical Design (CD-1/CD-3a)	0 days	Wed 11/1/17	Wed 11/1/17
15	1.3.2.3	sPHENIX Technical Dewsgin (CD-2)	0 days	Mon 7/2/18	Mon 7/2/18
16	1.3.2.4	sPHENIX Start Construction (CD-3b)	0 days	Wed 8/1/18	Wed 8/1/18
17	1.3.2.5	sPHENIX Installed and Ready for Beam	0 days	Tue 6/1/21	Tue 6/1/21
18	1.3.3	**LDRD Milestones & Critical Tasks**	**781 days**	**Mon 10/3/16**	**Mon 9/30/19**
19	1.3.3.1	LDRD Start and End	781 days	Mon 10/3/16	Mon 9/30/19
20	1.3.3.8	Complete MoU LANL-ALICE	0 days	Fri 12/9/16	Fri 12/9/16
21	1.3.3.3	Setup ALICE Readout Test Stands	0 days	Fri 2/17/17	Fri 2/17/17
22	1.3.3.4	Complete final sPHENIX Readout Design Review	0 days	Wed 7/26/17	Wed 7/26/17
23	1.3.3.5	Complete Final MAPS Detector Design (CD-1)	0 days	Thu 11/16/17	Thu 11/16/17
24	1.3.3.6	sPHENIX Test Beam	21 days	Fri 2/1/19	Fri 3/1/19
25	1.3.3.7	MAPS Final Design (CD-2/CD-3)?	0 days	Mon 10/3/16	Mon 10/3/16
26	1.5	**sPHENIX Project**	**1217 days?**	**Mon 10/3/16**	**Tue 6/1/21**
27	1.5.1	**sPHENIX Project Management**	**1217 days**	**Mon 10/3/16**	**Tue 6/1/21**
28	1.5.1.1	Level 3 Project Manager	1217 days	Mon 10/3/16	Tue 6/1/21
29	1.5.1.2	Mechanical Liason Engineer	1217 days	Mon 10/3/16	Tue 6/1/21
30	1.5.1.3	Electronics Liason Engineer	1217 days	Mon 10/3/16	Tue 6/1/21
31	1.5.2	**sPHENIX Mechanics Integration**	**289 days**	**Thu 11/2/17**	**Tue 12/11/18**
32	1.5.2.1	Stave Support Frame & Global Interface to sPHENIX	**115 days**	**Thu 11/2/17**	**Wed 4/11/18**
37	1.5.2.2	**Cooling System**	**25 days**	**Wed 8/1/18**	**Tue 9/4/18**
41	1.5.2.3	**Safety Systems**	**70 days**	**Wed 9/5/18**	**Tue 12/11/18**
45	1.5.2.4	**Stave Assembly Tooling**	**45 days**	**Thu 4/12/18**	**Wed 6/13/18**
49	1.5.3	Mechanics Final Design Review	**12 days**	**Thu 6/14/18**	**Fri 6/29/18**
53	1.5.4	**MAPS Inner Barrel Review (CD-2/3)**	**12 days**	**Mon 7/2/18**	**Tue 7/17/18**
57	1.5.5	**Productions**	**534 days?**	**Thu 6/14/18**	**Tue 6/30/20**
58	1.5.5.1	Full Pre-Production-Mechnical System Mock Up Test	90 days	Thu 6/14/18	Wed 10/17/18
59	1.5.5.2	**Procurements**	**180 days?**	**Wed 8/1/18**	**Tue 4/9/19**
60	1.5.5.2.1	**CERN Procurements**	**180 days?**	**Wed 8/1/18**	**Tue 4/9/19**
65	1.5.5.2.2	**Non-CERN Procurements**	**107 days**	**Wed 8/1/18**	**Thu 12/27/18**
80	1.5.5.3	**Assembly and Testing at BNL**	**400 days**	**Wed 12/19/18**	**Tue 6/30/20**
89	1.5.6	**Installation**	**131 days**	**Wed 7/1/20**	**Wed 12/30/20**
94	1.5.7	Ready for beam	0 days	Wed 12/30/20	Wed 12/30/20

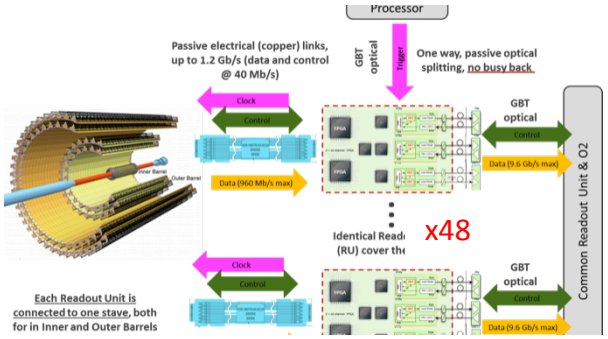


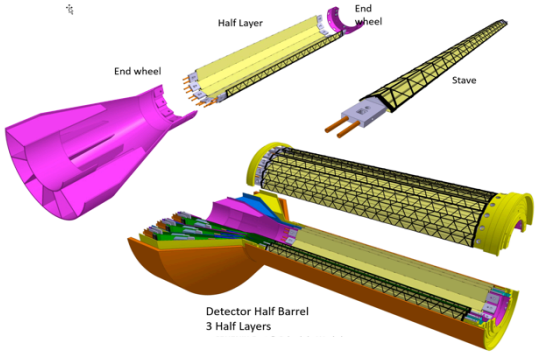
About 6 months of schedule float

From 09/2016 review

Cost Base for Major Items

- MAPS and Staves
  - ALICE ITS production
- Readout
  - ALICE ITS RU and CRU production
- Electronics Interface to sPHENIX/DAQ
  - FVTX/PHENIX experience
- Slow control, DCM-II etc.
  - FVTX/PHENIX experience
- Mechanical structures and cooling
  - ALICE ITS inner tracker desgin
  - FVTX/PHENIX experience





From 09/2016 review

Major Item Cost Estimate

From 09/2016 review

sPHENIX MAPS Inner Tracker Cost Estimate									
3 MAPS layers	Updated: 9/2/2016		LANL STD Labor Rates w/ o OH		LANL STD Labor Rates w/o OH				
FY16 dollars			No Funding Profile						
	R&D	R&D		Construction (k$)		Comments	Contingency	M&S OH	Full M&S Cost with Contingengy (k$)
	LANL (k$)	Collaboration (k$)							
		M&S	Labor Cost w/o Cont. & OH	M&S	Labor Cost w/o Cont.				
Produce & Test MAPS Staves at CERN	205.4			945.7	139.7	Alice production	0.4	0.25	1654.975
							0.4	0.25	0
Procure and Test RDO boards	17.6			265.7	15.5	Alice production	0.4	0.25	464.975
Procure and Test CRU boards	16.9			271.7	1.6	Alice production	0.4	0.25	475.475
sPHENIX readout R&D	203.4						0.4	0.25	0
DAQ integration	104.5						0.4	0.25	0
							0.4	0.25	0
Setup 2 ALICE Readout Teststand	52.9					Alice production	0.4	0.25	0
Procure and Test SamTec cables	3.2			27	0.3	Alice production cost	0.4	0.25	47.25
Procure and Test Optical links	1			81.6	0.6	Alice production cost	0.4	0.25	142.8
							0.4	0.25	0
Procure and Test LV, Cables etc	28.6			100	1.6	Alice production cost	0.4	0.25	175
Racks	8.6						0.4	0.25	0
Chiller & Cooling Plant	41.8	20	23.4	40	1.6	Alice production; may need to modify them to fit sPHENIX	0.4	0.25	105
Safety system	35.4	20	36.4				0.4	0.25	35
Mechnical integration	65.1	50	78.5				0.4	0.25	87.5
Assembly Jigs	48.37	20	24.6	100	0.9	Alice production; may need to modify them to fit sPHENIX	0.4	0.25	210
Test beam	99.6						0.4	0.25	0
							0.4	0.25	0
End wheels				34	1.6	Alice production	0.4	0.25	59.5
Cylindrical Structure Shells				11	1.6	Alice production	0.4	0.25	19.25
Detector half barrels				13	1.6	Alice production	0.4	0.25	22.75
Service half barrels				120	1.6	Alice production	0.4	0.25	210
Detector and Service Half Barrels				21	1.6	Alice production	0.4	0.25	36.75
Two Half Support Structures				50	1.6	Alice production; may need to modify them to fit sPHENIX	0.4	0.25	87.5
Total	932.37	110	162.9	2080.7	171.4				3833.725
	LDRD fully burdened	R&D M&S	R&D Labor	Prod. M&S	Prod. Labor				Pod. M&S with Cont. & OH

Participating and Interested Institutions

- LANL - Readout & FEMs, mechanical design
- MIT – Mechanical integration, cooling system, stave assembly and testing at CERN and BNL,
- LBNL – Carbon structure design and production, LV/HV PS and controls, system assembly and test
- BNL – Integration and services, safety and monitoring
- UT-Austin – MAPS readout electronics and testing
- Univ. of Colorado – sPHENIX DAQ/DCM-II integration
- Univ. of New Mexico – LV cabling & connectors
- New Mexico State University – Offline tracking and simulations
- Univ. of IL of Chicago – Stave assembly and testing, simulation and offline analysis
- Iowa State University – Assembly and testing, simulations
- Georgia State University - Slow control and monitoring, safety system
- Florida State University - Offline and simulations
- Univ. of California, Los Angeles – Assembly and testing, simulations
- Univ. of California, Riverside – Assembly and testing, simulations
- RIKEN/RBRC, Japan – Assembly and testing, integration
- Yonsei, Korea – MAPS QA, simulations
- Czech Group – Stave assembly and electronics testing at CERN
- CCNU – ALICE/ITS upgrade, 5th layer experience, assembly and testing

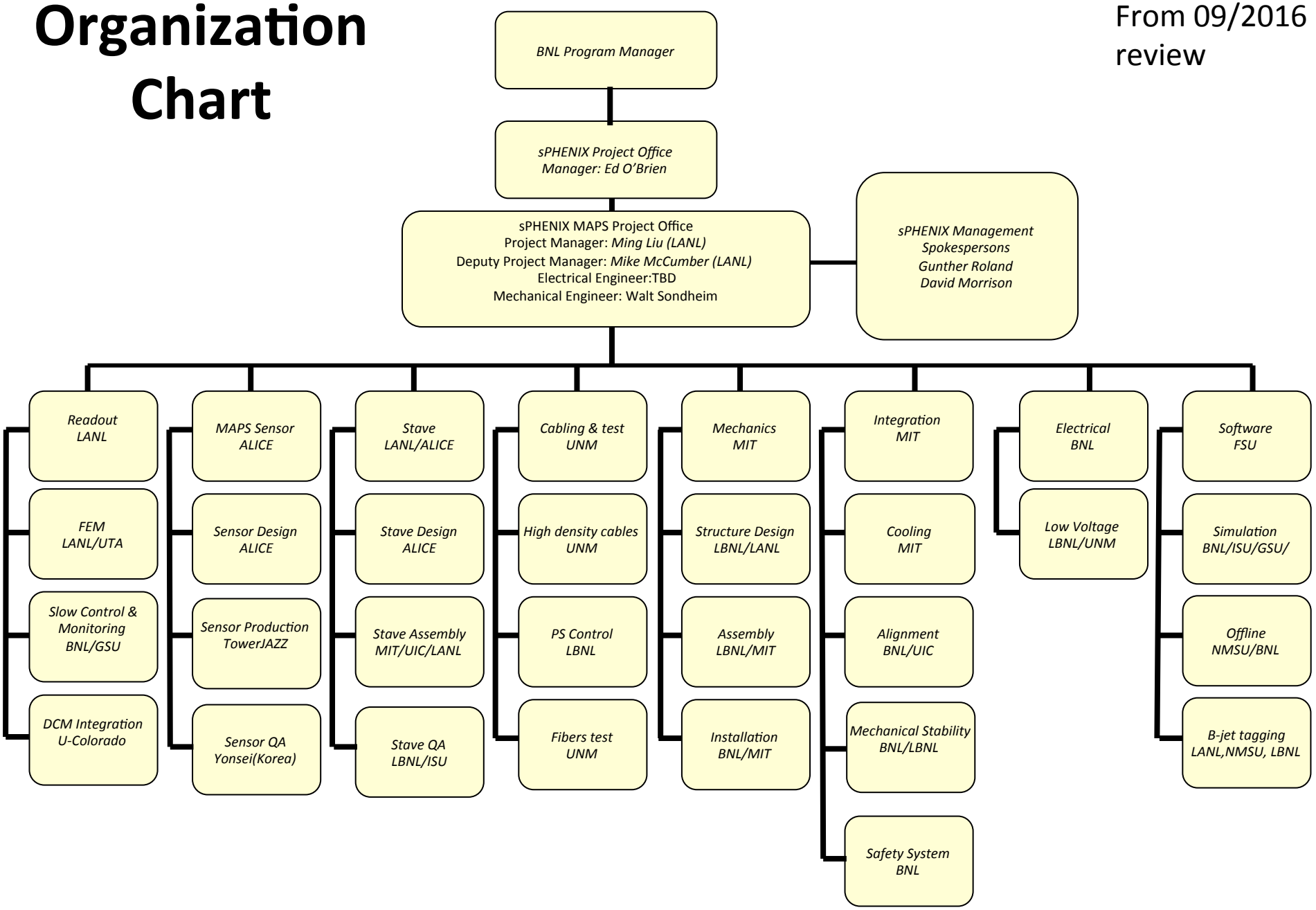
Potential collaboration

Major Tasks and Lead Institutions for sPHENIX MAPS Project

- MAPS chips production
  - LANL et al
- Readout integration and testing
  - LANL, BNL, UT-Austin, U-Colorado
- Mechanical structures
  - LBNL
- Mechanical integration
  - MIT, LBNL
- LV, HV PS and controls
  - LBNL
- MAPS stave production - assembly and testing at CERN
  - MIT, LANL and others
- Full module assembly and test in US
  - LBNL, MIT and others
- Online software
  - BNL, GSU?
- Offline software - detector simulation, geometry, offline tracking
  - NMSU, FSU, LANL
- Physics simulations - to make "Money Plots"
  - LBNL, LANL, U-Colorado and all

Organization Chart

From 09/2016 review



Outline

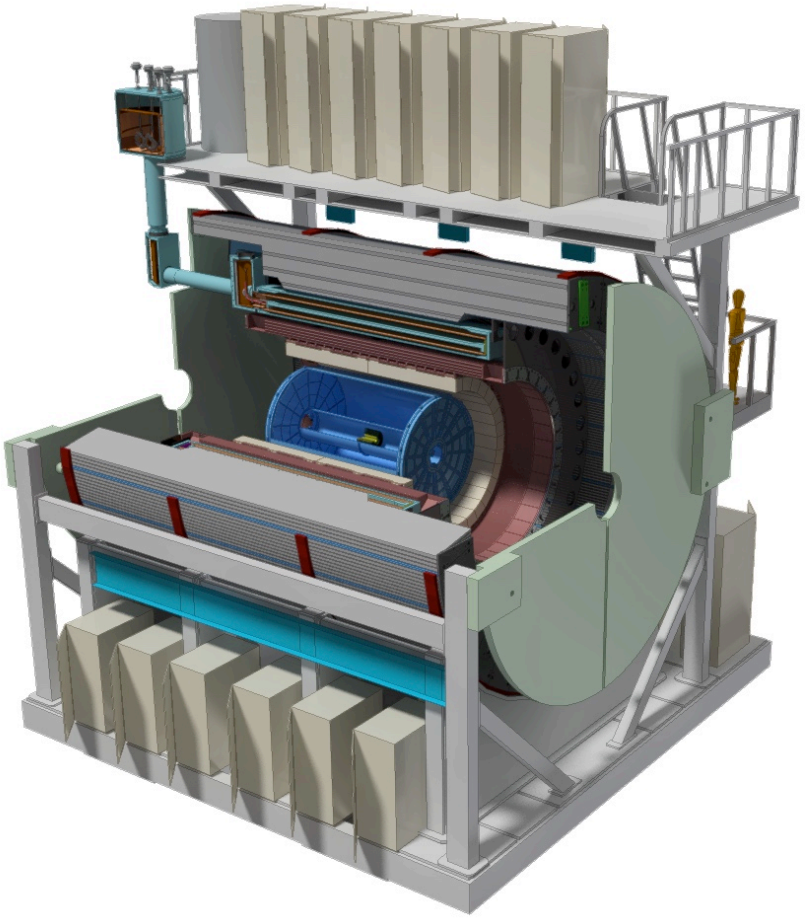
- Motivation
- MAPS Inner Tracker Scope
- MAPS Project Status
- MAPS R&D at CERN and LANL

Full MAPS MIE proposal writing

Santa Fe HF-Jet/MAPS Workfest 1/5-7, 2017

https://indico.bnl.gov/conferenceDisplay.py?ovw=True&confId=2641

WBS of the Latest sPHENIX MIE



From Ed O'Brien

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

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

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

A new MIE to build the full MAPS detector

WBS of MAPS Inner Tracker

- WBS 1.3 – A MAPS Telescope
  - About 10 staves
  - Optimized geometry for maximum physics, TBD
  - $500K (including contingency)
  - Day-1 physics for b-jet
  - Test run and demonstrator for full MAPS detector if not ready

- WBS 1.13 – The full MAPS inner tracker
  - 3 layers of MAPS detectors
  - $5M construction fund from DOE
  - A new MIE

Recent Development

- sPHENIX/MAPS discussion at MIT, Oct. 2016
  - discussed MIT's interest and responsibility
  - Major tasks to lead – Mechanical integration & Cooling system
  - MIT Physics and Bates Engineering Groups
  - Resource and timeline
    - Engineers and Techs
    - Students and postdocs

- LBNL joins sPHENIX 12/2016
  - LV/HV PS and controls
  - Mechanic carbon structures
  - System assembly and test
  - Physics simulations

- A joint R&D on CRU
  - TPC & MAPS
  - BNL Physics and Instrumentation

Visited ALICE/CERN, Nov. 2016
- LANL-ALICE/ITS MOU achieved
- Associate member on ITS
- Joint R&D for sPHENIX/MAPS
- Help ALICE/ITS & train sPHENIX experts
- Produce MAPS chips for sPHENIX

A MIE being developed for the full MAPS …

- Started communication with DOE
- Develop a plan to identify tasks, resources and timeline
- First full doc by the end of Jan 2017
  - For discussions with DOE in Feb. budget meeting, LANL & LBNL
- Possible timeline of MAPS MIE
  - Submitted and reviewed in FY17, establish DOE "mission need"
  - Federal budget request by DOE in Feb 2018
  - Fund available FY20 for construction ("normal route")
- Needed:
  - advanced funding in mid 2018 to produce full staves following the completion of ALICE/ITS production at CERN
  - Or high level "agreement" to secure CERN facility for sPHENIX

MAPS MIE Proposal Writing

More on Cesar's talk

Overleaf | PROJECT | HISTORY & REVISIONS | SHARE | PDF | JOURNALS & SERVICES | SIGN UP | SIGN IN

Source | Rich Text | Edit | Find

```
\documentclass{DOEproposal}
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% NSF proposal generation template style file.
% based on latex stylefiles  written by Stefan Llewellyn Smith and
% Sarah Gille, with contributions from other collaborators.
%
% Additions by Ronni Grapenthin, New Mexico Tech.
%
% Obviously it is your responsibility to make sure that everything
% is, in fact, in agreement with the most current NSF Grant
% Proposal Guide and the respective Program's solicitation!
% This is all provided `as-is' and no blame or responsibility
% for anything that went wrong will be taken.
%
% Good luck!
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

\usepackage{amsmath, amsthm, amssymb}
\usepackage{latexsym}
\usepackage{epsfig}
\usepackage{epstopdf}
\usepackage{graphicx}
\usepackage[footnotesize,bf]{caption}
\usepackage[final]{pdfpages}
\usepackage{hyperref}
\hypersetup{
    colorlinks=true,        % false: boxed links; true: colored links
    linkcolor=blue,         % color of internal links
    citecolor=black,        % color of links to bibliography
    filecolor=magenta,      % color of file links
```

Preview | Manual | Auto | warning

Monolithic-Active-Pixel-Sensors (MAPS) MIE proposal for sPHENIX Experiment at RHIC

A proposal submitted to the DOE Office of Science
November 18, 2016

Invited Proposal:
DOE Office of Science Program Manager:

Proposing Organization: Los Alamos National Laboratory

Collaborating Institutions: MIT
LBNL
BNL
Univ. of Texas -Austin
UCLA
UCR
NMSU
UNM
UC
UIC
ISU
GSU
FSU
Yonsei
RIKEN/RBRC

Principal Investigator: Ming X. Liu

Phone: 505-412-7396
Email: mliu@lanl.gov

Requested Funding: $2.0M/year for three years
Total Request: $6.0M

Budget Summary:

Institution	Year 1	Year 2	Year 3
LANL	$500K	$500K	$500K

Outline

- Motivation
- MAPS Inner Tracker Scope
- MAPS Project Status
- MAPS R&D at CERN and LANL

Full MAPS MIE proposal writing

Santa Fe HF-Jet/MAPS Workfest 1/5-7, 2017

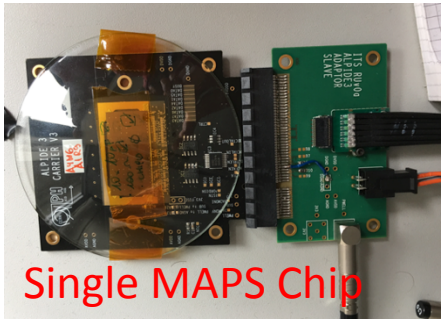
https://indico.bnl.gov/conferenceDisplay.py?ovw=True&confId=2641

Status of MAPS R&D at ALICE/CERN

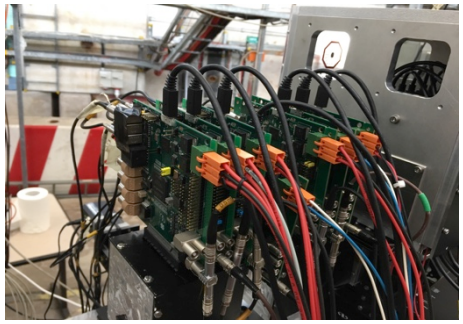
- MAPS chip readout with test board
  - Also tested at LANL
  - Telescope
- Multichip MAPS high speed readout
  - with the first prototype Readout Cards (RUv0)
  - MiniDAQ (MOSAIC board) test bench
- RU v0 tested to readout stave with high-speed, next version spring 2017
- RU fiber optics communication established with a prototype Common Readout Unit (CRU)
- Stave space frame being produced
- Service End Wheel being prototyped

Procurement for LANL LDRD R&D items

- Key R&D electronics and mechanic prototypes being produced for LANL LDRD

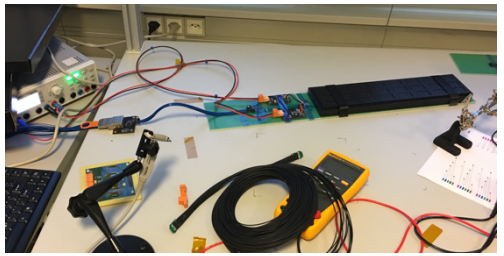

Single MAPS Chip

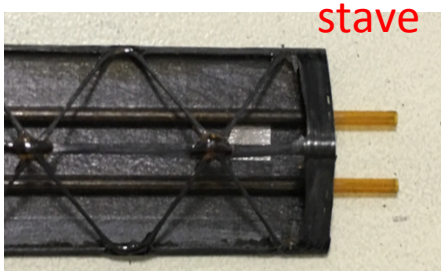
A 7-single-chip telescope




RUv0

MOSAIC Test Bench




stave


Service wheel

LANL LDRD Activities

MAPS is on LANL's 10-year strategic plan for key S&T

- LALN internal
  - Simulations
  - Electronics
  - Mechanics
- External collaboration
  - CERN/ITS group
  - ALICE US groups
- Lead people identified for key tasks
  - Team of experts
- Job AD out for a new staff
  - Several outstanding candidates

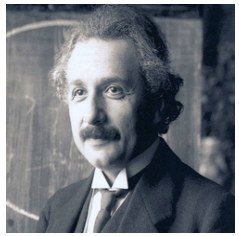

Mike McCumber


Sanghoon Lim


Sho Uemura


Pat McGaughey


Ming Liu


Mark Prokop

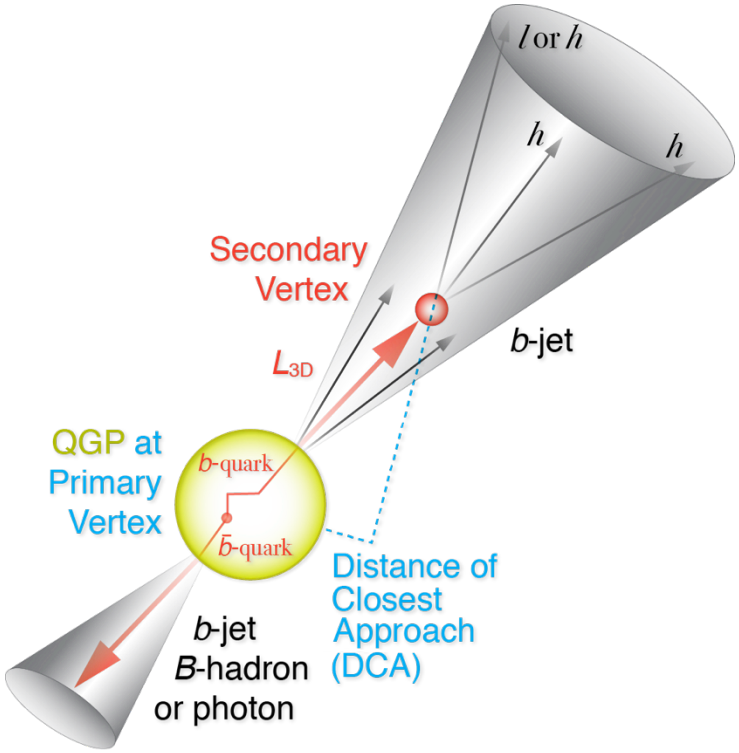

Walt Sondheim


Hubert van Hecke

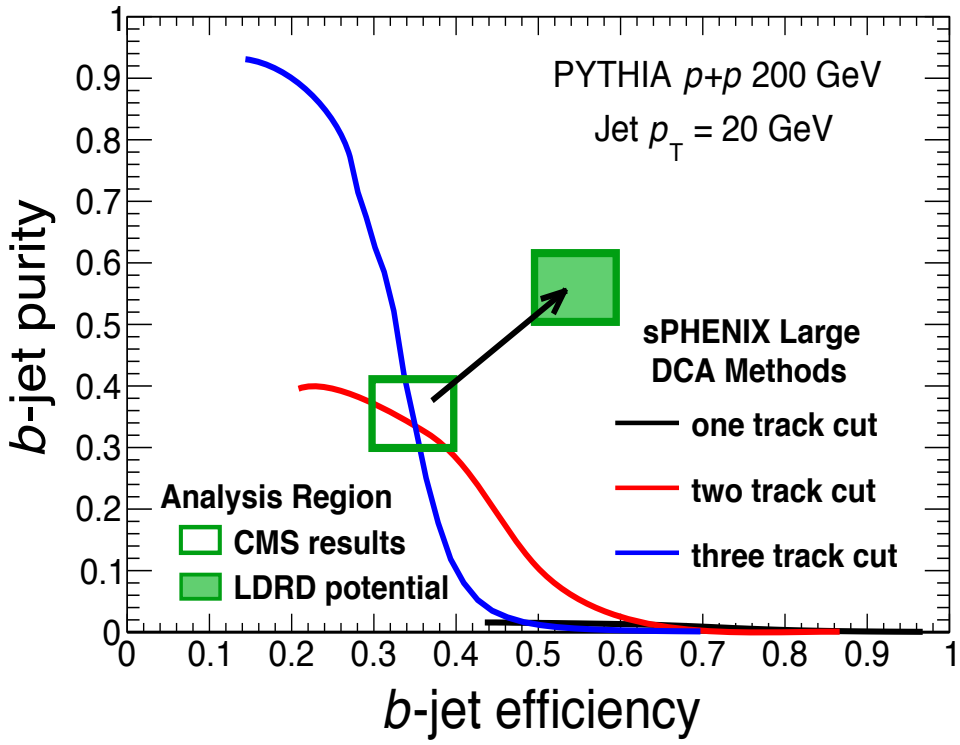

Darren McGlinchey

Experimental R&D Deliverables: Physics

LDRD Goal: much improved B-jet Identification in Heavy Ion Collisions



Secondary Vertexing Possible!

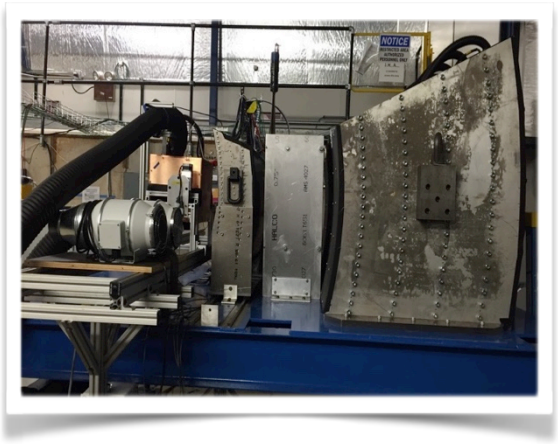


- A new b-jet identification with **high efficiency** and **high purity** is possible
- Figure of merit is ***efficiency*** *x* ***purity.*** Greatly enhancing the b-jet physics program, x4 improvement in FOM (compared to alternatives)

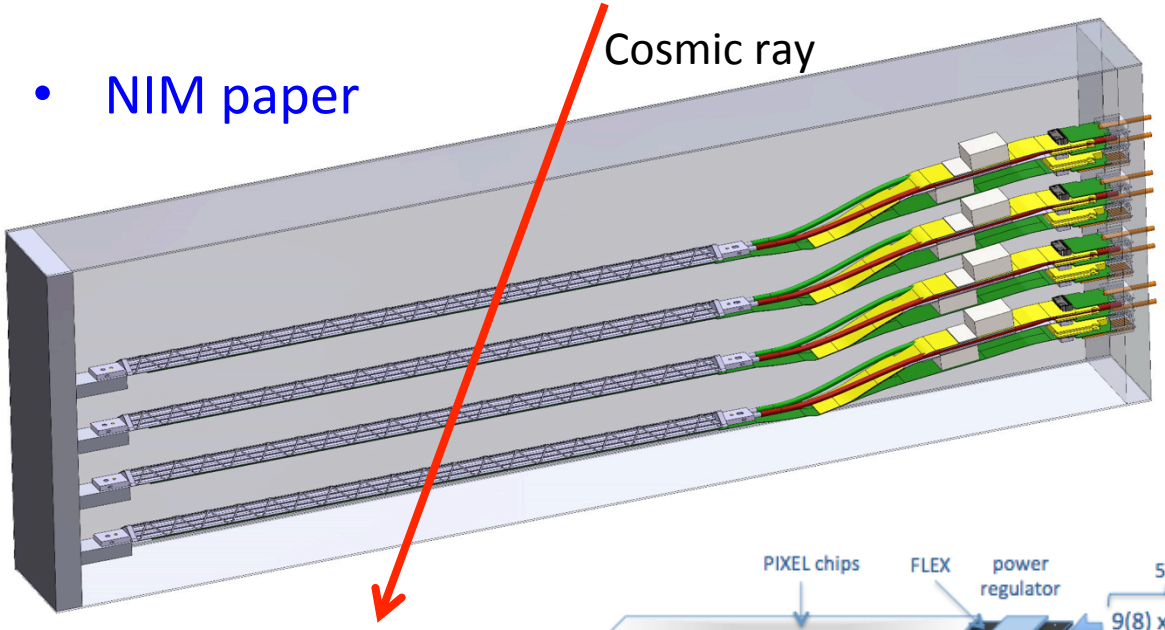
Experimental R&D Deliverables

a 4-Stave Telescope

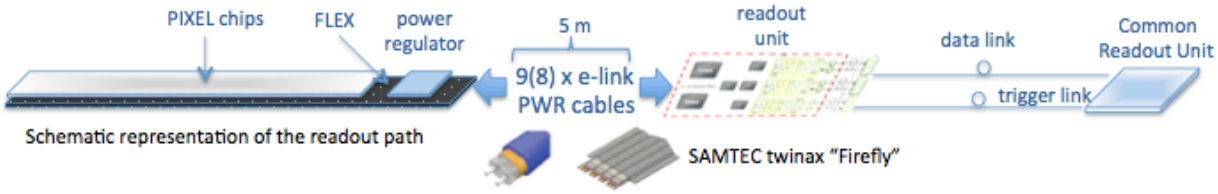
- Performance of prototype tracker
  - High speed readout of staves
  - Spatial resolution
  - Electrical and mechanical stability
  - Cooling etc.
- NIM paper



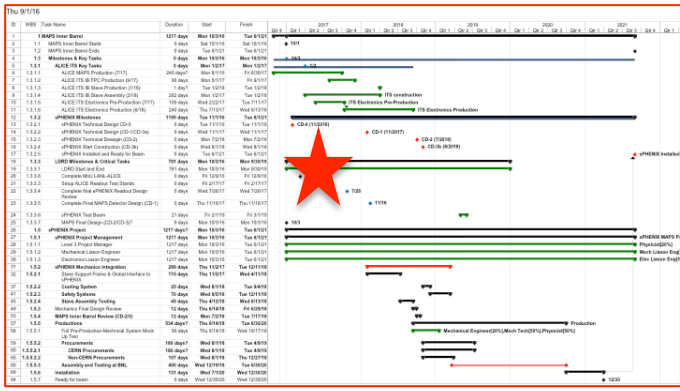
Beam test at Fermilab



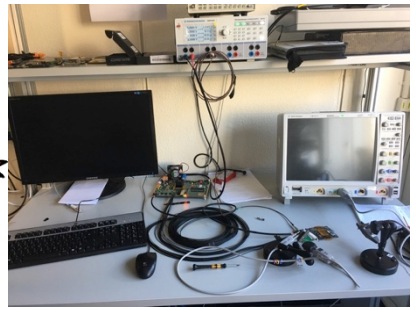
sPHENIX
Data Format



1st Milestone: LANL - ALICE/ITS MoU

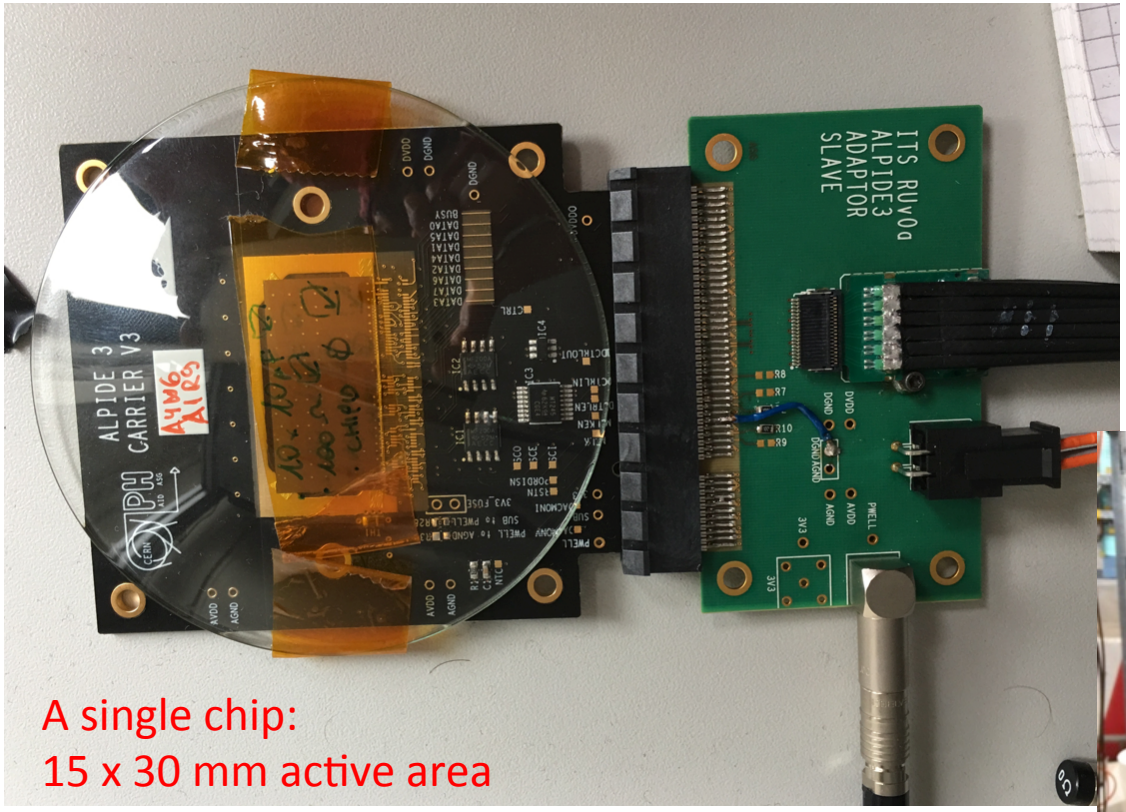


- CERN Visit to discuss MoU: November 10-15, 2016
  - Visited MAPS R&D and construction labs
  - Agreement on MoU established!
- LANL MoU with ALICE/ITS
  - Associate member on the ALICE/ITS project at CERN
    - Access all technical design files and documents
    - Access other technical resources, including Engineering and Computing support, joint R&D on LDRD project
    - Train LANL personnel on the job
  - Procurement of critical items from CERN
    - 5 single-chip MAPS readout evaluation boards
    - 1-2 high-speed readout out test boards (MOSAIC test bench)
    - 4+ Readout-Unit and 2+ Common-Readout-Unit prototypes and associated electronics components, including CERN GBT optical links
    - Mechanical support frame prototypes
- LDRD milestones developed to match:
  - ALICE R&D and production schedule
  - sPHENIX proposed installation schedule



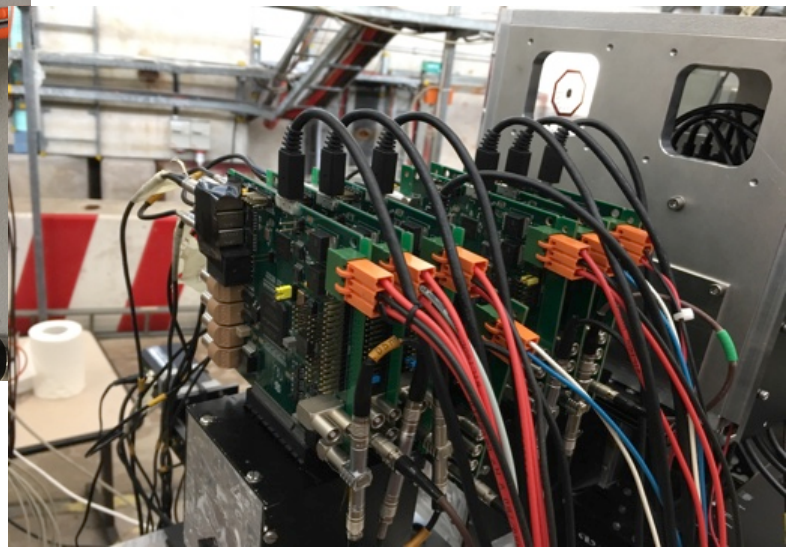
High speed readout test

R&D at LANL:MAPS Chips



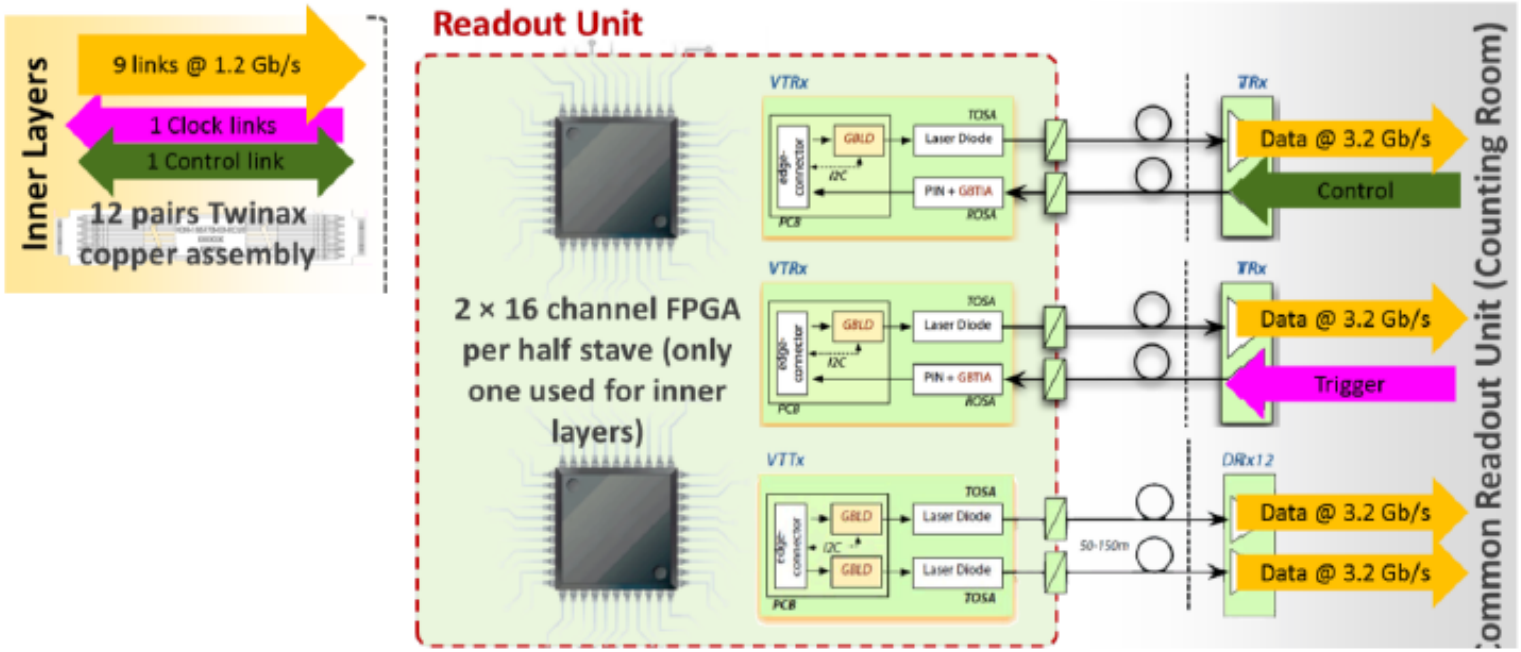
A single chip:
15 x 30 mm active area

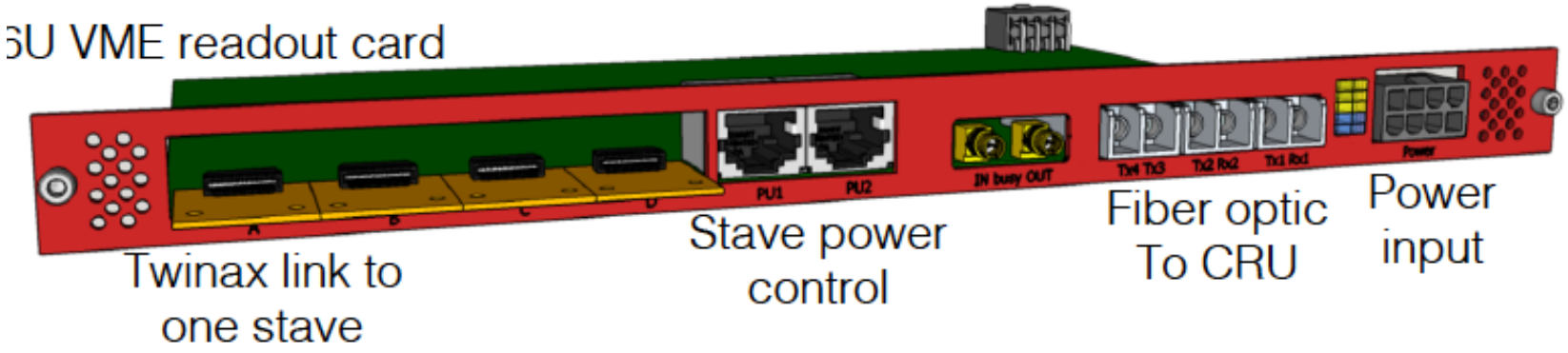
A 5-single-chip MAPS telescope



- Have one chip with slow readout working;
- 5 more on the way to build a telescope at LANL

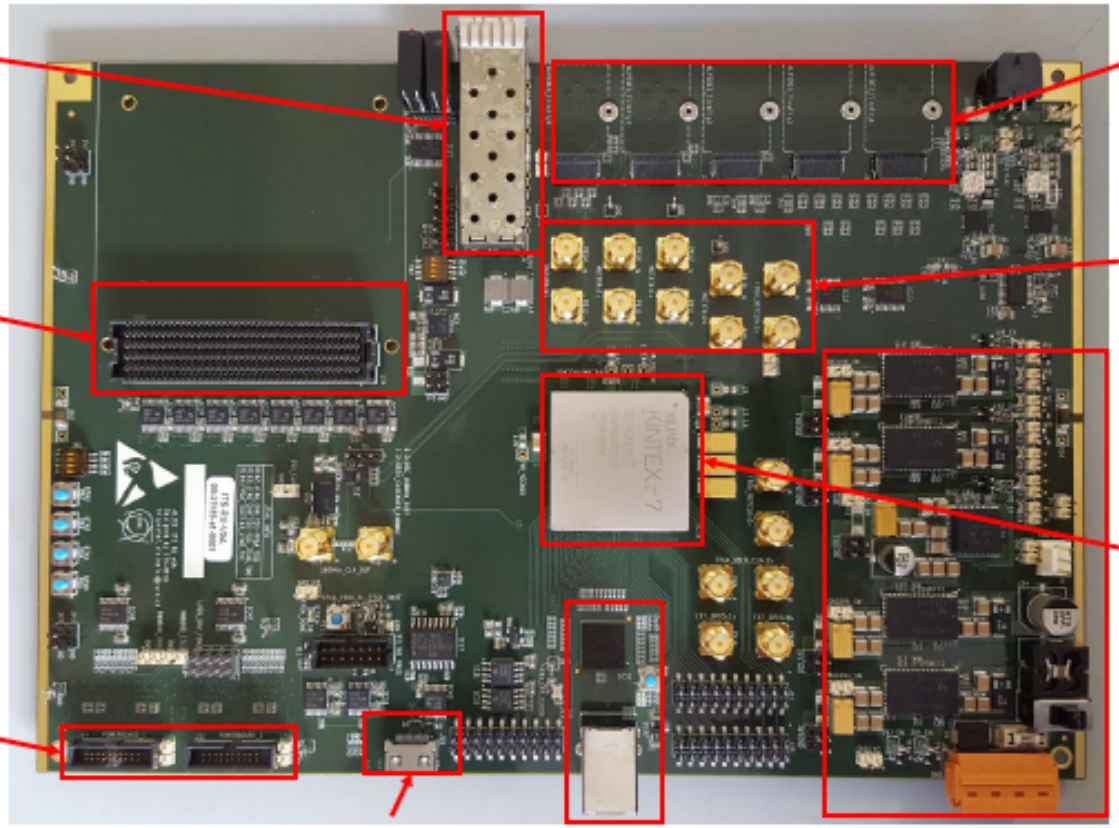
ALICE Readout Unit Design





ALICE Readout Unit – Prototype 0

From Pat McGaughey



Low risk, currently being tested by ALICE

Expect version '0' readout unit at LANL in spring, 2017

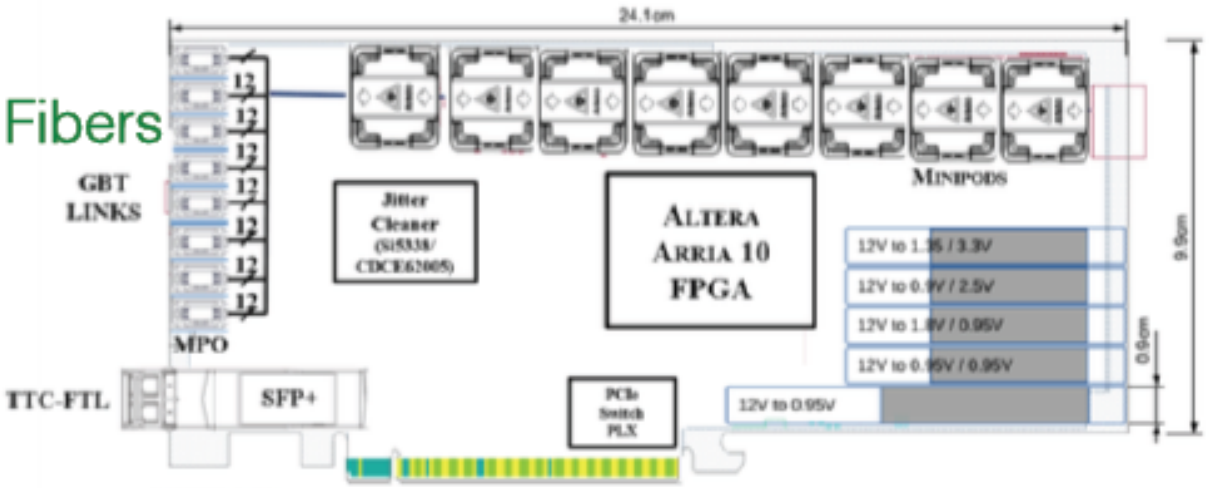
ALICE Common Readout Unit

From Pat McGaughey

PCI express card

(a) PCie40.

Avago optical engines

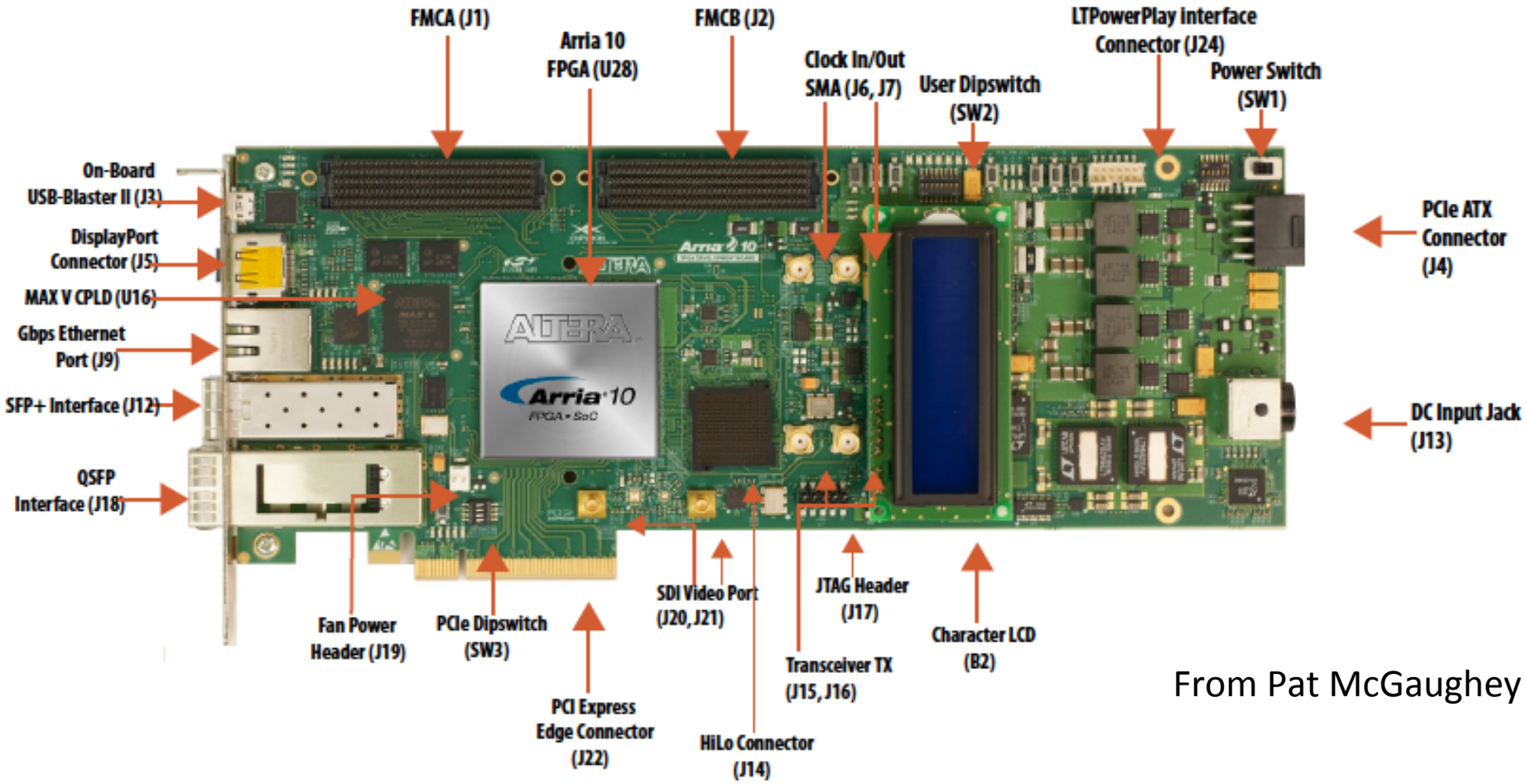


(b) PCIe40 Schematic.

- Each CRU reads out 2 RUs
- Expected at LANL summer 2017 for testing
- Also exploring other options, commercial boards, ATLAS/FELIX boards etc.

Commercial Altera Development board for Common Readout Unit Prototyping and Programming

Figure 1-2: Overview of the Development Board Features



From Pat McGaughey

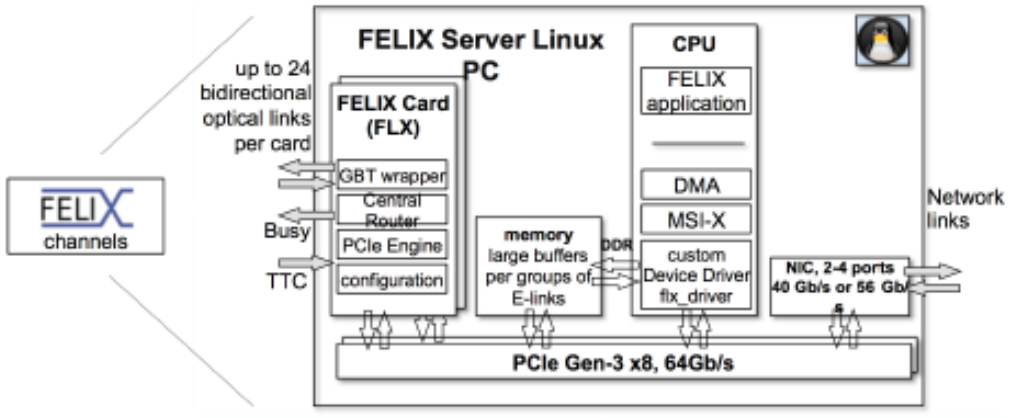
Risk reduction – Allows FPGA code development with same FPGA, fiber optic and PCI-x readout. Ordered

Joint Effort on “CRU”: TPC-MAPS

ALICE/CRU and ATLAS FELIX being studied

ATLAS EXPERIMENT FELIX Hardware

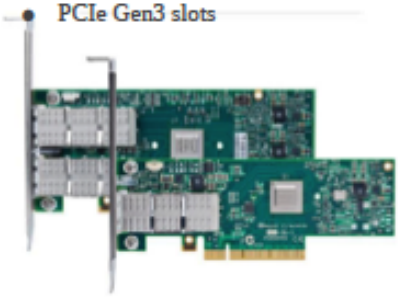
From Kai Chen FELIX



- Server Linux PC
- Up to two PCIe interface cards with Xilinx Ultrascale FPGA, depending on bandwidth needed (for two cards: using 2× PCIe slots Gen3 ×8 lanes, leaving enough lanes for the NIC(s))
- NIC, 40 or 100 Gb/s Ethernet interfacing or InfiniBand

SuperMicro X10SRA-F used for development

- Broadwell CPU, e.g. E5-1650V4, 3.6 GHz
- PCIe Gen3 slots



Mellanox ConnectX-3 VPI

- 2× FDR/QDR Infiniband
- 2× 10/40 GbE

Summary of MAPS Project

- LANL/LDRD MoU with ALICE/ITS established
- Key R&D item procurement from CERN in progress
- Physics and detector simulation work underway
- sPHENIX initial cost, schedule and risk management plan developed for MAPS MIE
- MIE pre-proposal writing in progress

To do:

Early "Agreement" btw DOE/sPHENIX with ALICE/CERN critical

Jin's talk

Register today: Workfest

https://indico.bnl.gov/conferenceDisplay.py?ovw=True&confId=2641

MAPS MIE proposal and HF-jet Topical Group Workfest

5-7 January 2017 *Santa Fe, NM*
US/Mountain timezone

Search

- **Overview**
- Timetable
- Registration
  - Modify my registration
- List of registrants

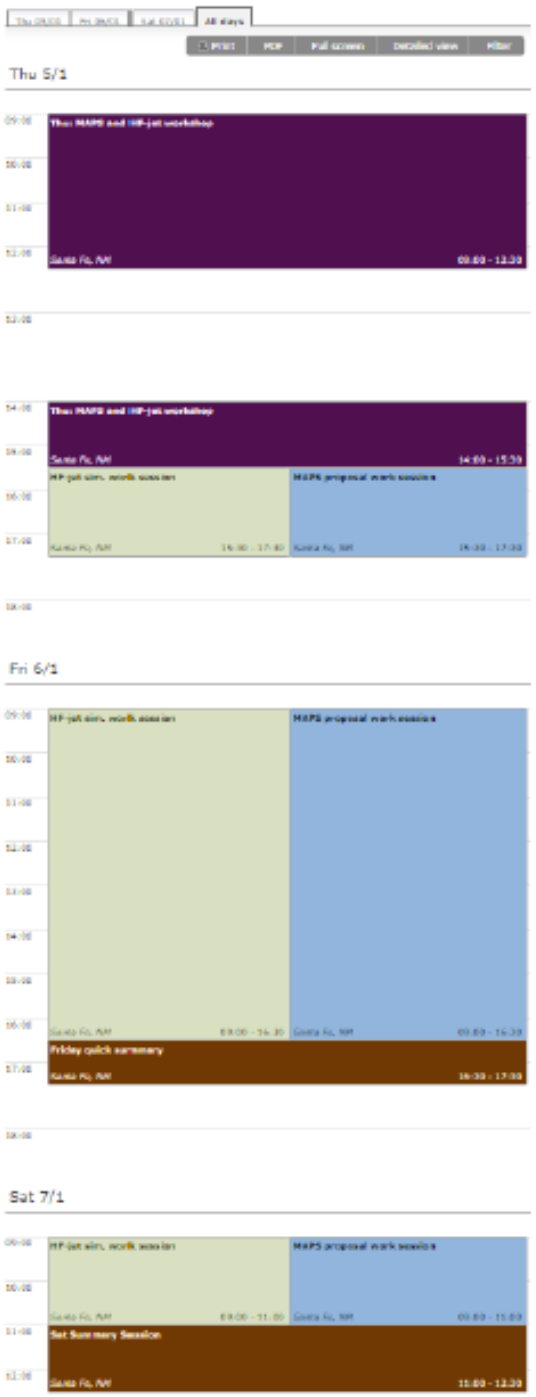
MAPS detector group and HF-jet topical group invites you to this sPHENIX workfest @ Santa Fe, NM. The goals of this workfest are

- MAPS detector group
  - Make significant progress on MAPS MIE proposal
  - Update the cost and schedule to be ready for discussion with DOE in Feb budget meeting
  - Develop additional physics cases for MAPS detector beyond sPHENIX scientific proposal
- HF-jet topical group
  - Produce near final *b*-jet tagging performance plot for MAPS proposal and QM2017 conference
  - Advance the tracking detector simulation towards new baseline simulation configuration
  - Develop B-meson simulations

The workfest is organized as

- Thu Jan 5: workshop style talks summarize current considerations on MAPS detector, HF-jet simulations and new ideas. Bluejean broadcast will available for remote participations.
- Fri Jan 6: parallel work sessions on MAPS proposal and on simulations, with brief summary session at the end of the day.
- Sat Jan 7: parallel work sessions in the morning. Summary session in noon and work sessions in the afternoon.

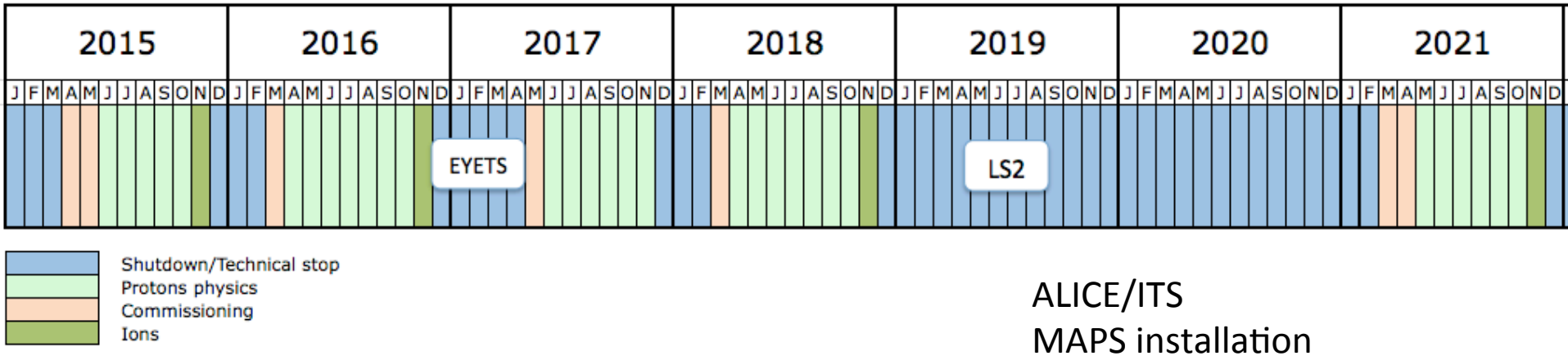
Dates:	from 05 January 2017 08:00 to 07 January 2017 18:00
Timezone:	US/Mountain
Location:	*Santa Fe, NM* Hotel to be announced
Chairs:	Dr. Liu, Ming Dr. Huang, Jin Dr. McCumber, Michael
Additional info:	***Accommodation*** Local organizers at LANL is arranging for conference hotel with block room and conference setup. Details to be announced.



McCumber

Backup slides

Long Term LHC Schedule



ALICE/ITS
MAPS installation

sPHENIX MAPS
R&D

sPHENIX MAPS
Assembly and
Test @CERN

sPHENIX MAPS
Installation @BNL

DOE MIE Process and Challenges

- Contact for new scientific proposals
  - Associate Director for NP (Tim), who will then identify point of contact for the project
    - Jehanne Gillo
- For a project with Total Estimated Cost(TEC) < $10M
  - no CD process needed: good news
  - The 3-layer MAPS inner tracker fit this scope

- For a project with TPC > $2M
  - "includes all engineering and fabrication costs, needs to be identified individually in the federal budget as Major Item of Equipment(MIE)" - concern over timeline
  - If submitted and reviewed and DOE "mission need" approved in FY17
    - the earliest date to receive fund is FY20, Oct. 2019.
  - Federal budget prepared 2-year in advance
  - DOE budget request to Congress ~Feb 2018
  - It is hard to have a complete proposal submitted, reviewed and approved for "DOE mission need" and have this MIE included in the Feb. 2017 DOE budget request (~3 months from now)
    - while we are still waiting for (CD0 and) CD1 approval from DOE
  - http://science.energy.gov/np/facilities/project-development/

- Challenges to match ALICE/ITS production schedules
  - Early fund (~$1M) needed in the summer of 2018 to continue ALICE/ITS production line for sPHENIX MAPS staves
  - DOE-CERN agreement if delayed?

My Note:

- The normal MIE process may not match optimally with the current ALICE/ITS and sPHENIX installation and run schedules, need to work closely with DOE how to proceed
- Some minimum fund (~$1M) must be secured for the MAPS stave production at CERN following the completion of ALICE/ITS project, such as $$ from RHIC operation savings or foreign contributions etc.

Cost breakdown

ALICE

Activity	Material Costs	Manpower Costs	TOTAL COST / ITEM
1. Pixel Chip	4847	170	5017
1.1 CMOS Wafers	3611		3611
1.2 Thinning & Dicing	800		800
1.3 Series test	436	170	606
2 Inner Barrel	296	262	558
2.1 FPC (construction and test)	23	13	36
2.2 HIC (assembly and test)	250	150	400
2.3 SF & Cold Plate (constr. and test)	3	43	46
2.4 Stave assembly & test	20	56	76
3 Outer Barrel HIC	1447	1118	2565
3.1 FPC (construction and test)	247	88	335
3.2 HIC (assembly and test)	1200	1030	2230
4 Middle Layers Staves	142	322	464
4.1 Powerbus cables	70	3	73
4.2 SF & Cold Plate (constr. and test)	42	113	155
4.3 Stave assembly & test	30	206	236
5 Outer Layers Staves	284	896	1180
5.1 Powerbus cables	127	33	160
5.2 SF & Cold Plate (constr. and test)	97	245	342
5.3 Stave assembly & test	60	618	678

Chips:
1k/50k = 2%
- $100K

Staves:
68/120 = 60%
-$340K

Full cost recover
for CERN labor
-$500K
(cover in produc
labor cost)
"Buy staves"
and MoU

Total ~$1M

Cost breakdown

A Large Ion Collider Experiment

ALICE

Activity	Material Costs	Manpower Costs	TOTAL COST / ITEM
6 Inner Barrel Global Assembly	70	156	227
6.1 End-Wheels (E-W)	4	30	34
6.2 Assembly of Staves on E-W	16	12	28
6.3 Cylindrical Structural Shell	1	10	11
6.4 Detector Half-Barrels	6	7	13
6.5 Service Half-Barrels	36	84	120
6.6 Detector + Service Half-Barrels	7	14	21
7 Outer Barrel Global Assembly	135	407	542
7.1 ML End-Wheels	13	50	63
7.2 ML Assembly of Staves on E-W	10	21	31
7.3 OL End-Wheels	23	59	82
7.4 OL Assembly of Staves on E-W	12	32	44
7.5 Conycal Structural Shell	8	62	70
7.6 Cylindrical Structural Shell	20	55	75
7.7 Detector Half-Barrels	7	13	20
7.8 Service Half-Barrels	36	85	121
7.9 Detector + Service Half-Barrels	7	30	37
8 Integration in ALICE	91	262	354
8.1 Cage	61	153	215
8.2 Installation Tooling	30	109	139

Cost breakdown

A Large Ion Collider Experiment

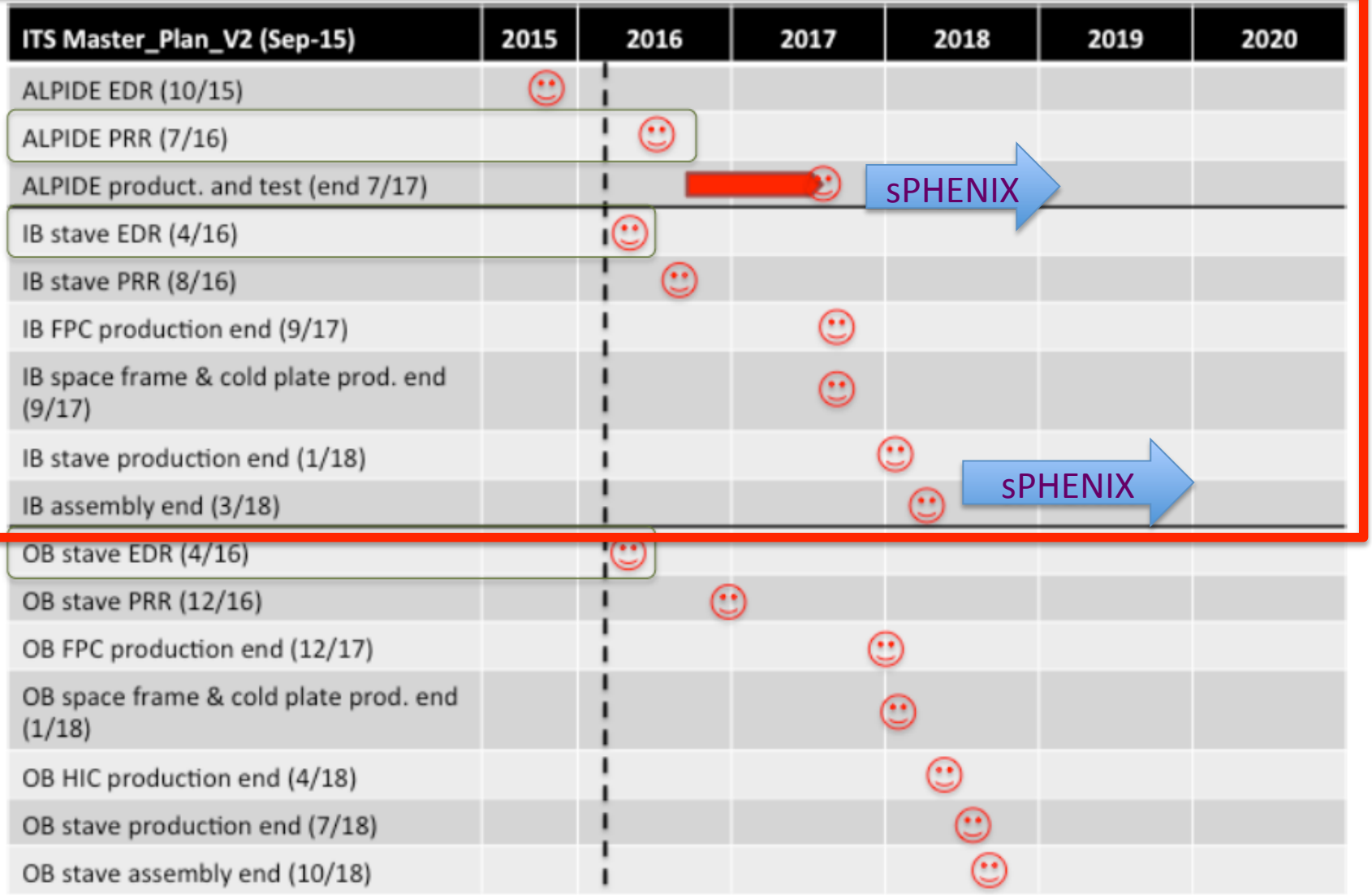
ALICE

Activity	Material Costs	Manpower Costs	TOTAL COST / ITEM
9 Readout Electronics	715	50	765
9.1 Data e-Links	82	50	132
9.2 Patch-panels	20		20
9.3 Readout Unit	469		469
9.4 Optical Links	144		144
10 Power distribution	1149	50	1199
10.1 Power Supplies	750		750
10.2 Power Distribution	242	50	292
10.3 Power Regulation	157		157
11. DCS	150		150
12. Cooling	620	0	620
12.1 Water Cooling Plant	470		470
12.2 Ventilation Humidity Plant	150		150
GRAND TOTAL	9947	3693	13640

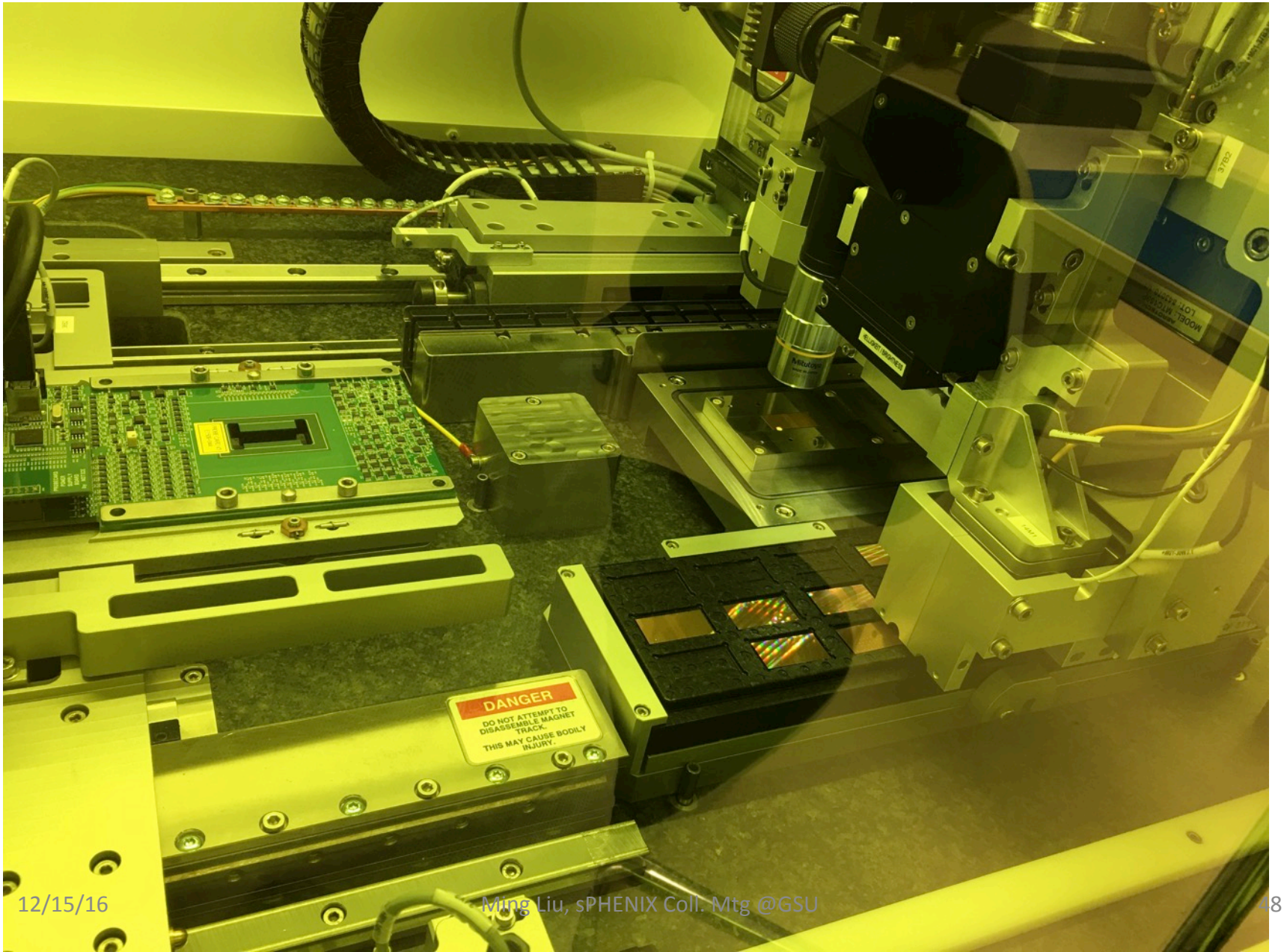
Milestones – ALPIDE, IB & OB Staves

A Large Ion Collider Experiment

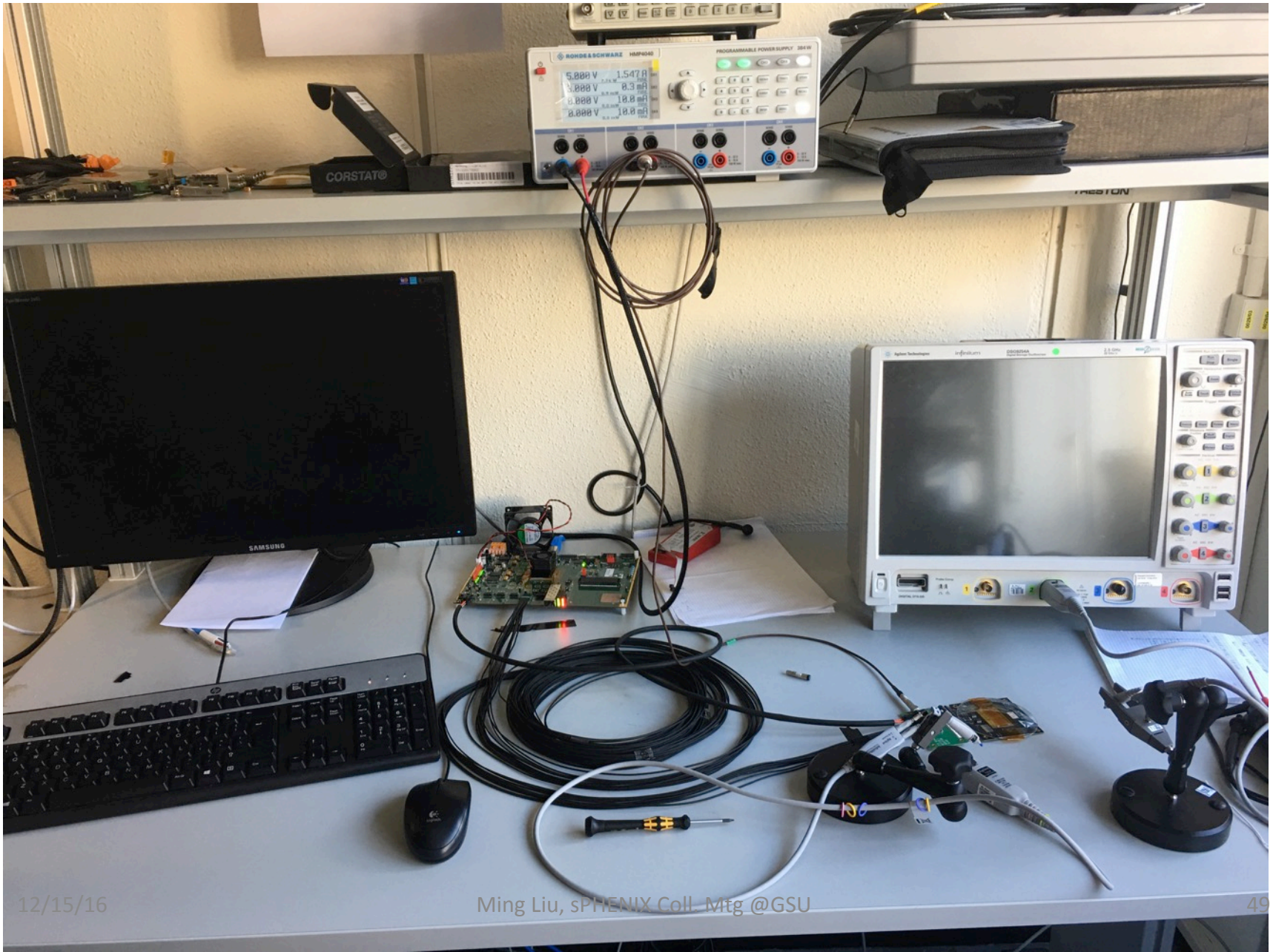
ALICE



Module Assembly Lab

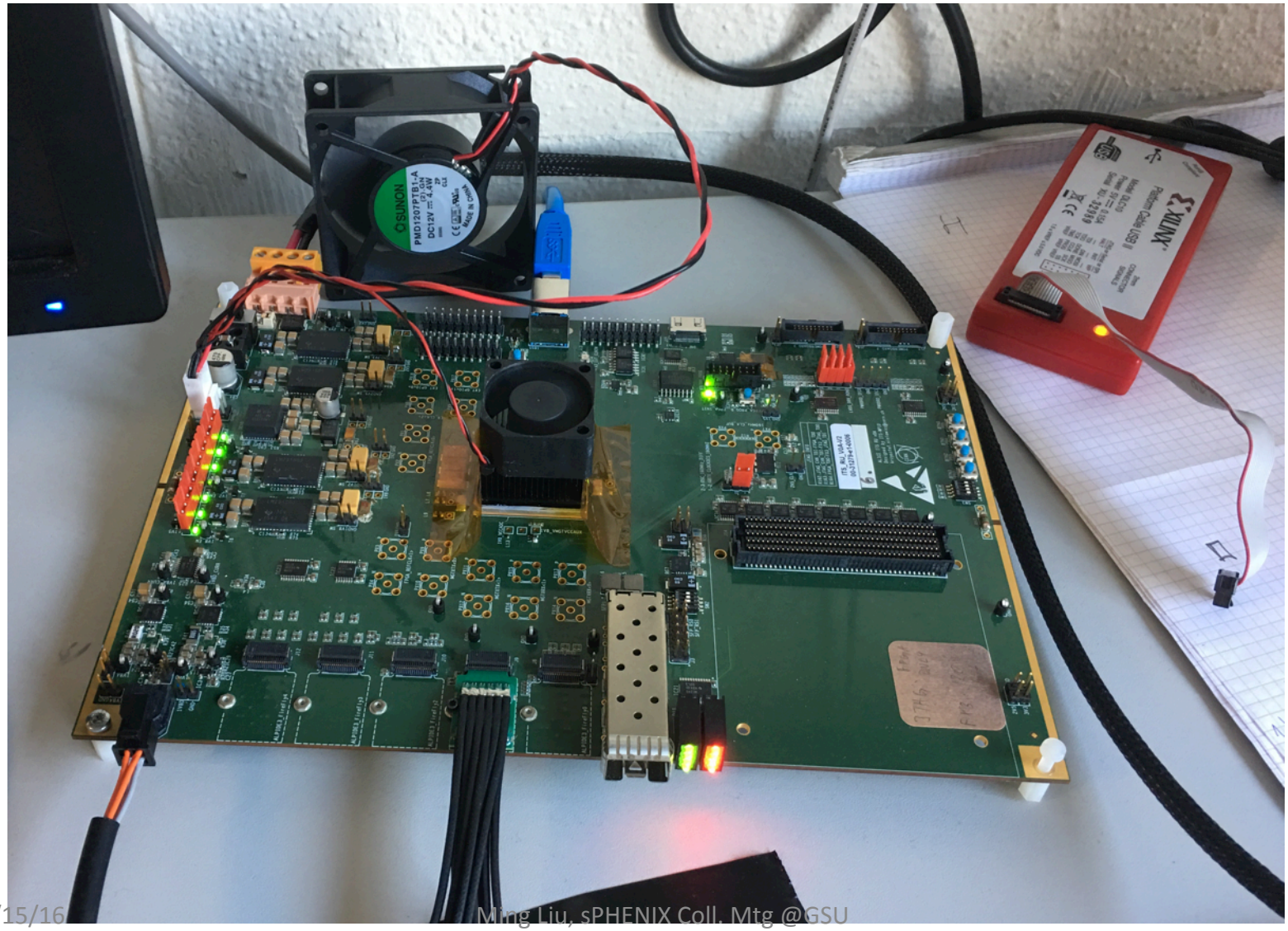


Readout Electronics Lab



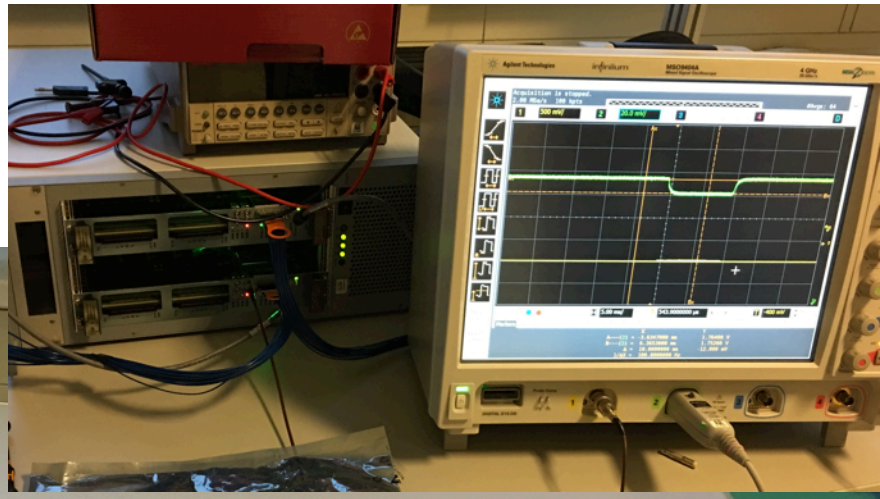
Readout Unit - V0

single module high-speed readout, USB or GBT fiber; no CRU yet



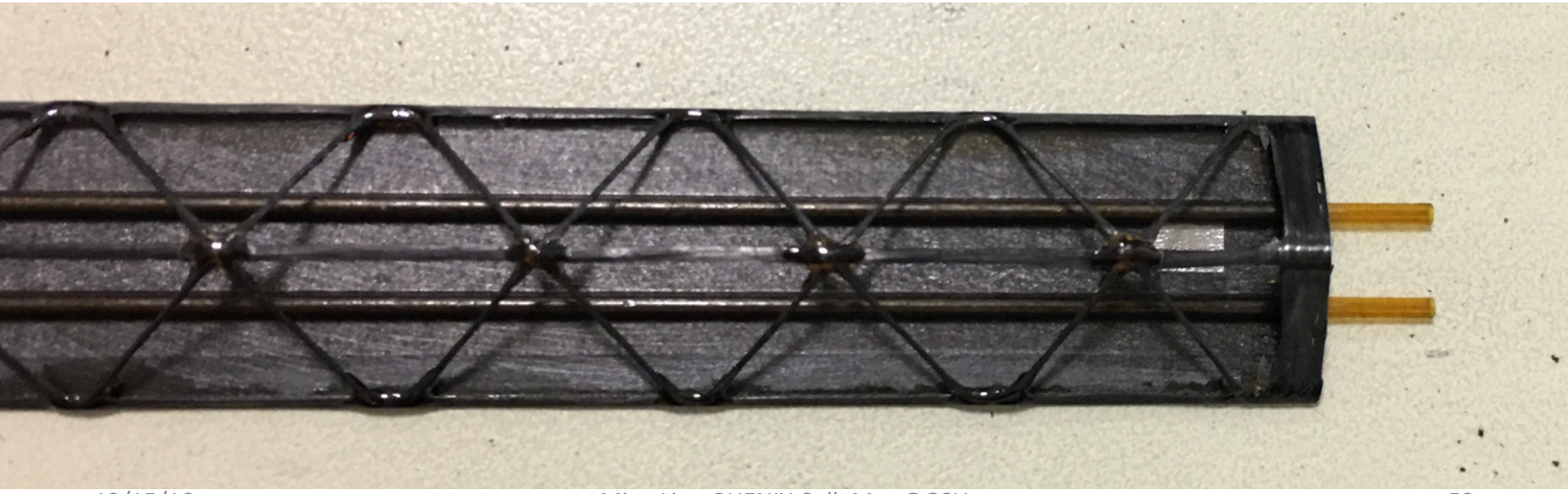
9-Chip Module High Speed Readout

Test Bench: MOSAIC Card



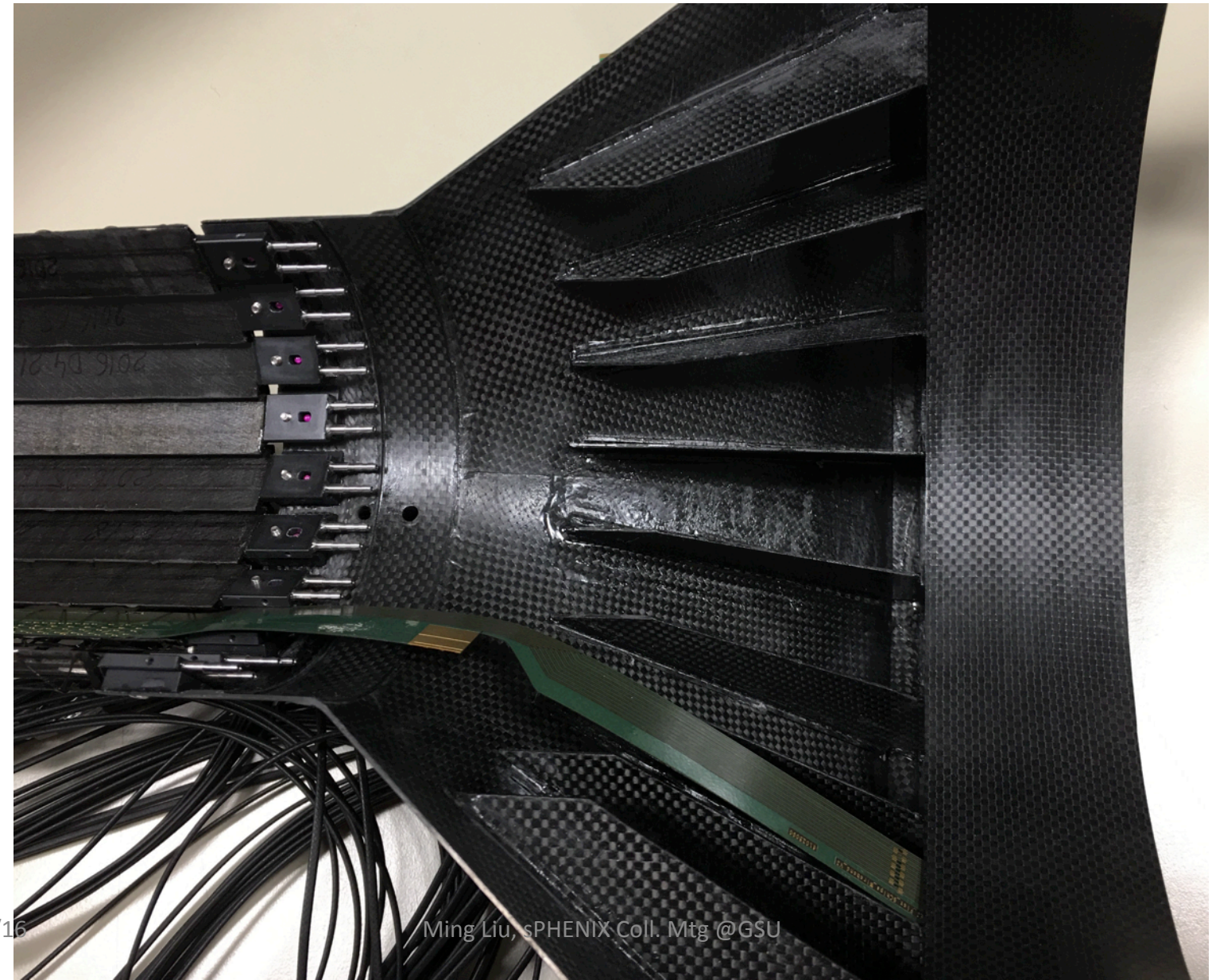
Stave Production

Very good progress, ahead of schedule

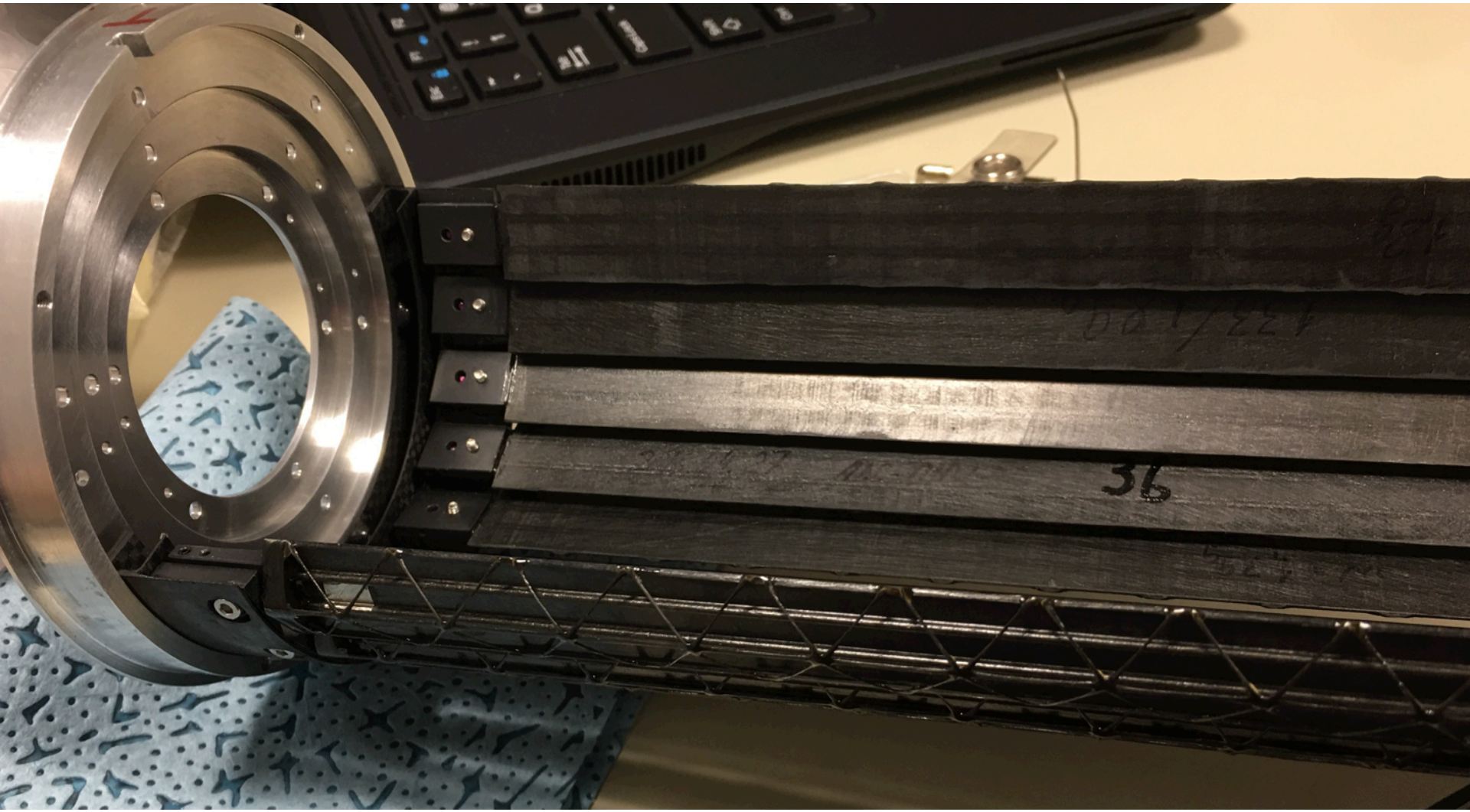


Mechanical Frames

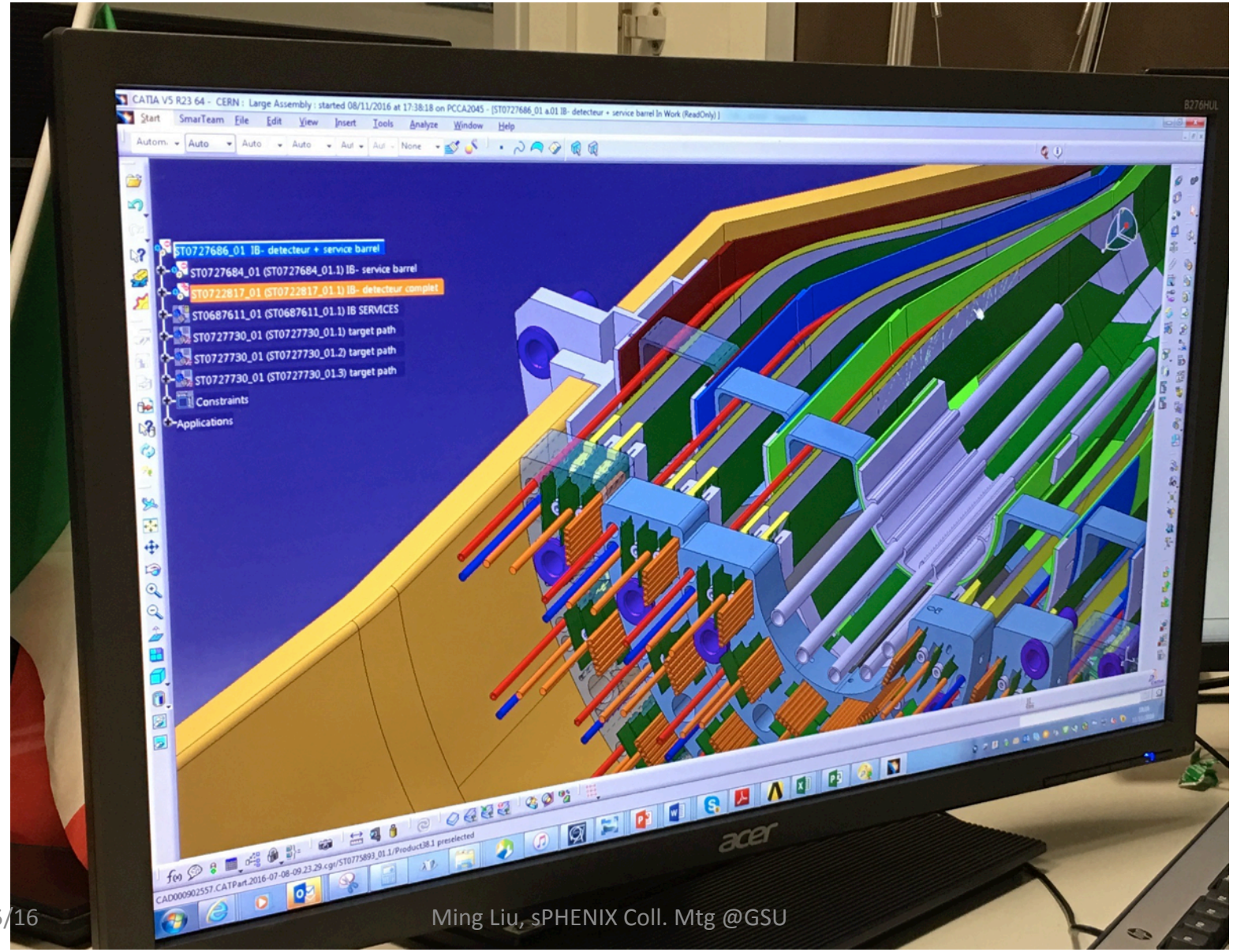
Service End Wheel



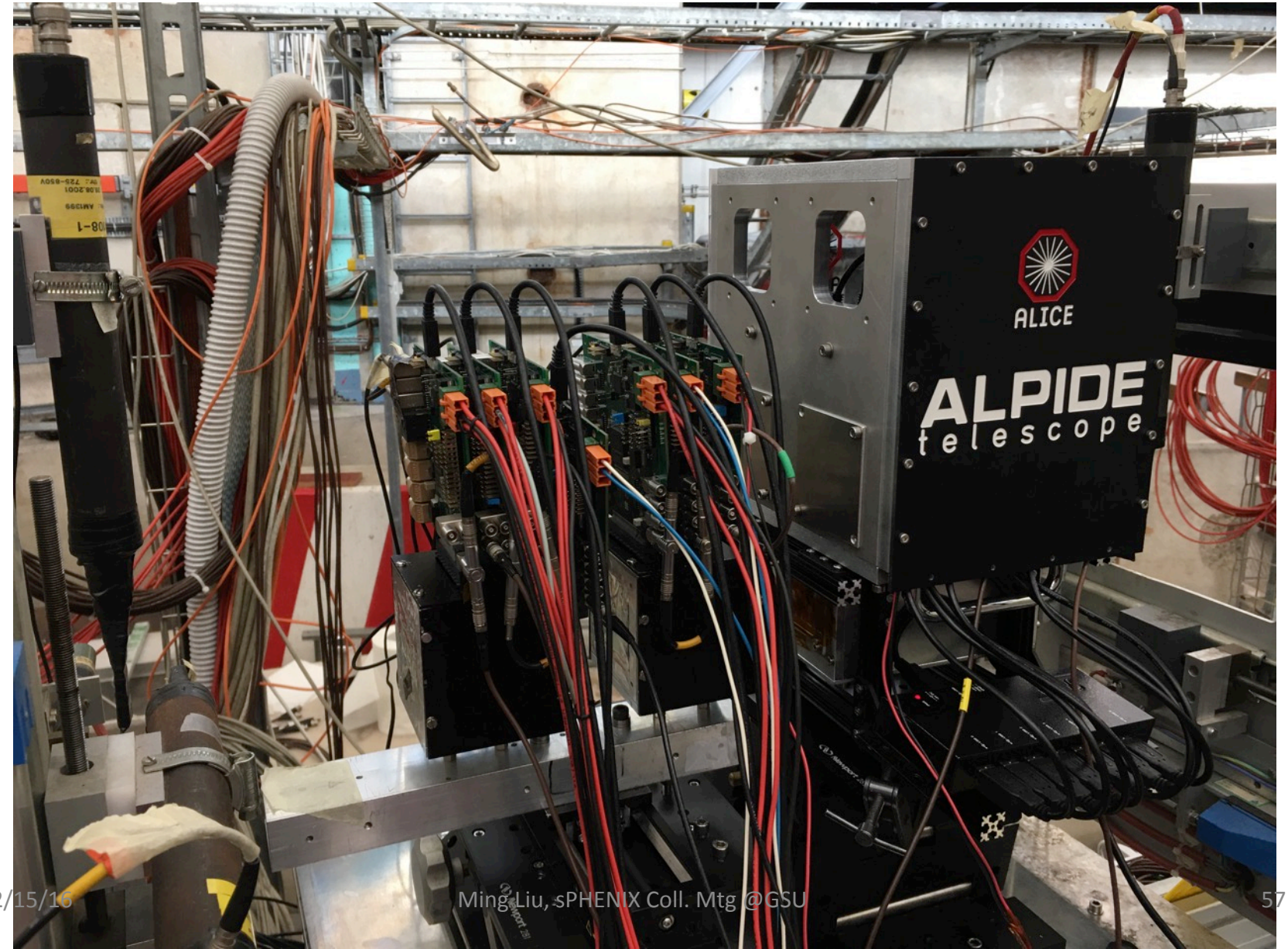
Staves



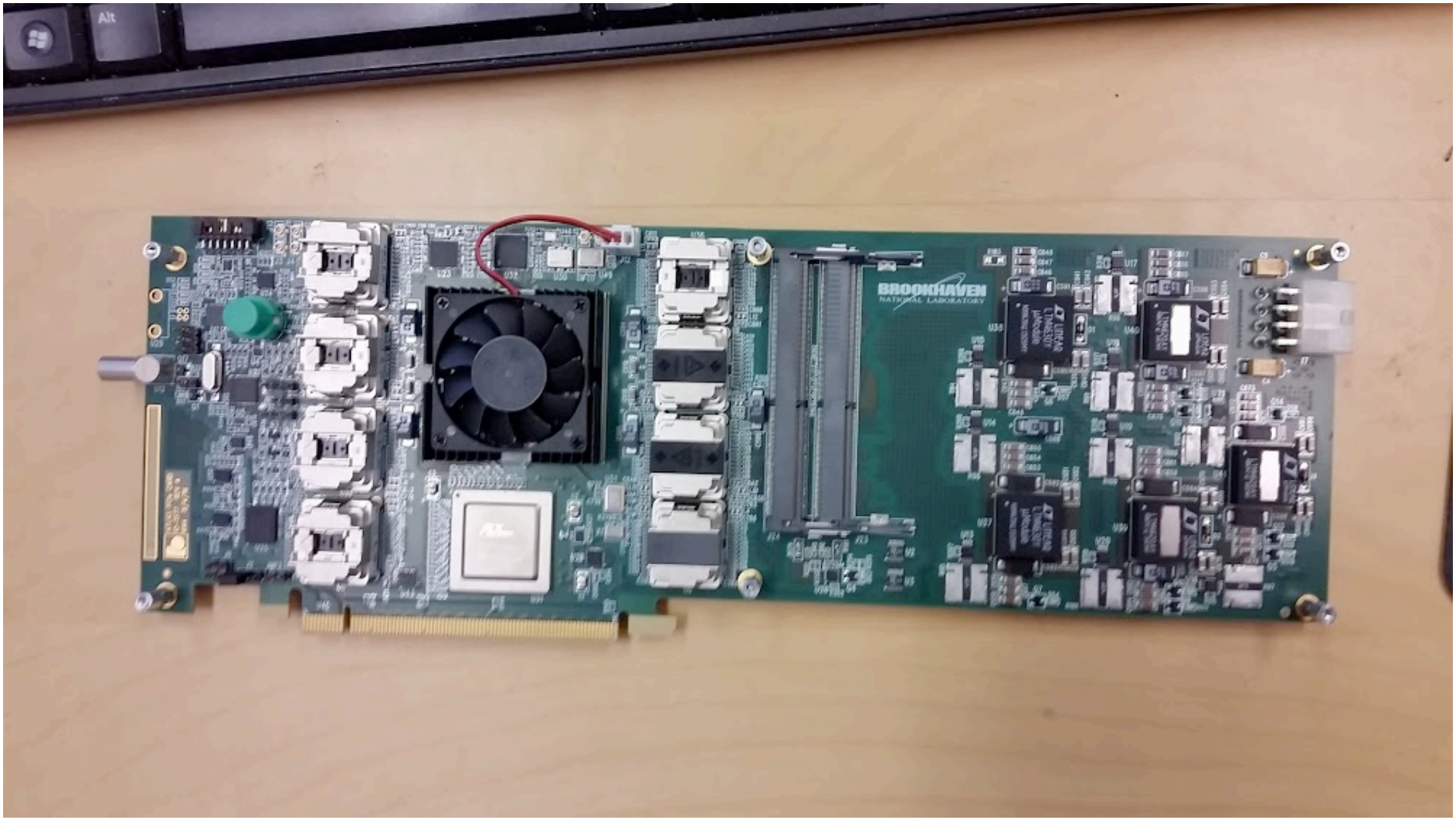
Mechanical End Wheel Design



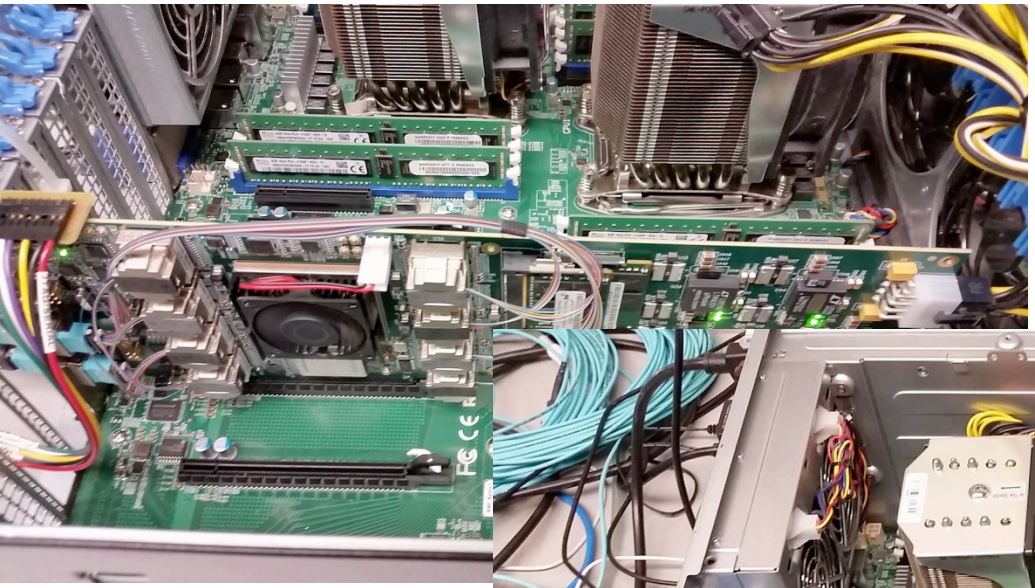
Test beam setup: 7 Single Chip Modules

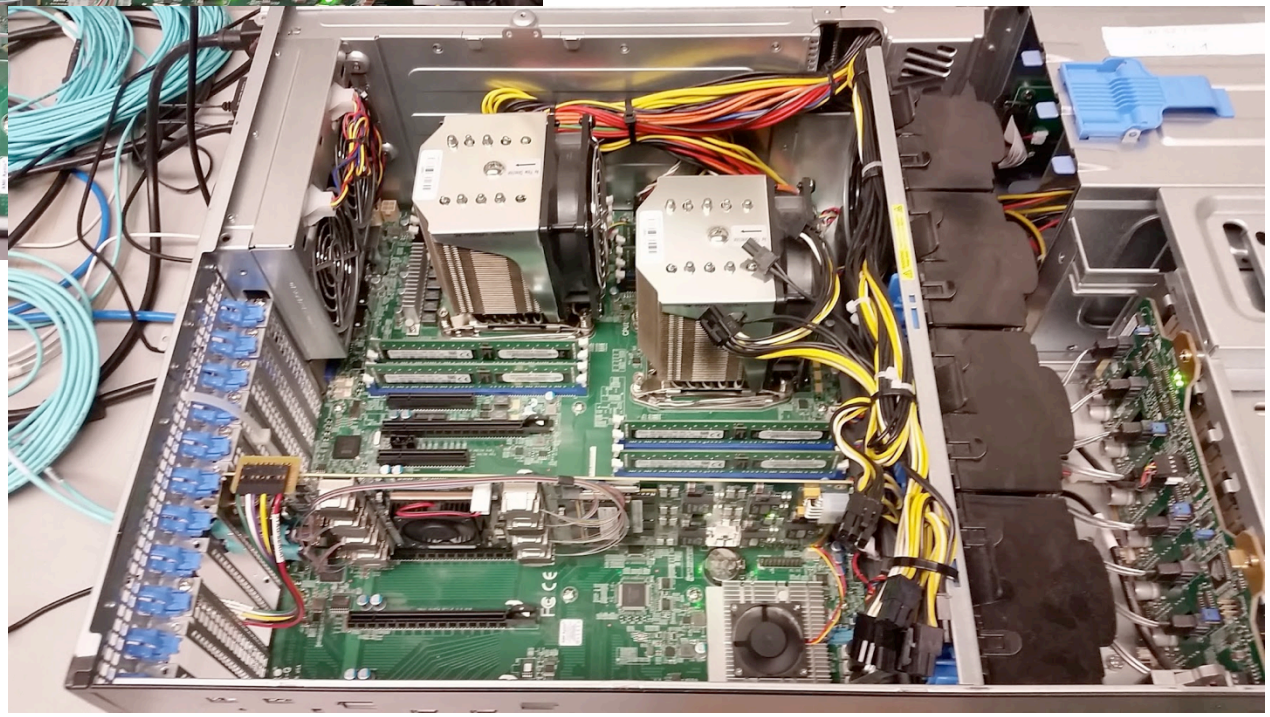


ATLAS FELIX Board @BNL



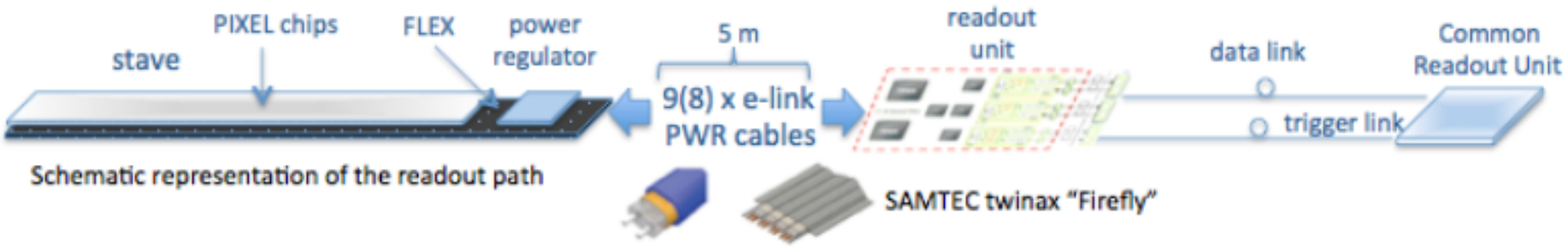
FELIX @BNL





From Mike McCumber

sPHENIX MAPS Data Bandwidth



ALICE ITS IB is physical signal dominated

Event multiplicity reduction: RHIC / LHC = 7000/20000 = 0.35
Collision rate increase: RHIC / LHC = 200 kHz / 150 kHz = 1.33

Continuous Stave-to-ROU link is ~50% bandwidth of ALICE ITS IB

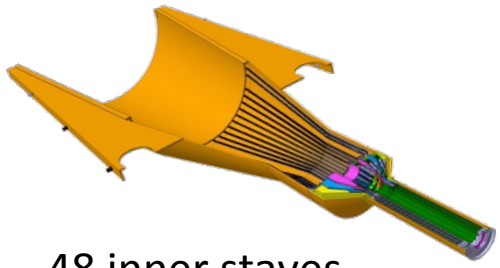
Trigger rate reduction: RHIC / LHC = 15 kHz / 50 kHz = 0.30

Triggered ROU-to-CRU link is only ~15% bandwidth of ALICE ITS IB

Readout Units Required for ITS & sPHENIX

Readout Units and GBT links for maximum design rates

Layer	Staves	Copper assemblies	Copper capacity	RUs per stave	RUs per layer	VTRx count	VTTx count	Data fibers	Control fibers	Data fibers capacity	Data fibers usage
			[Gb/s]							[Gb/s]	[%]
0	12	12	103.7	1	12	24	12	36	12	115.2	90.0
1	16	16	138.2	1	16	32	16	48	16	153.6	90.0
2	20	20	172.8	1	20	40	20	60	20	192	90.0
3	24	48	122.9	1	24	48	24	48	24	153.2	80.0
4	30	60	153.6	1	30	60	30	60	30	192	80.0
5	42	168	376.3	1	42	84	42	126	42	403.2	93.3
6	48	196	430.1	1	48	96	48	144	48	460.8	93.3
Total		520	1497.6		192	384	192	576	192	1670	



48 inner staves

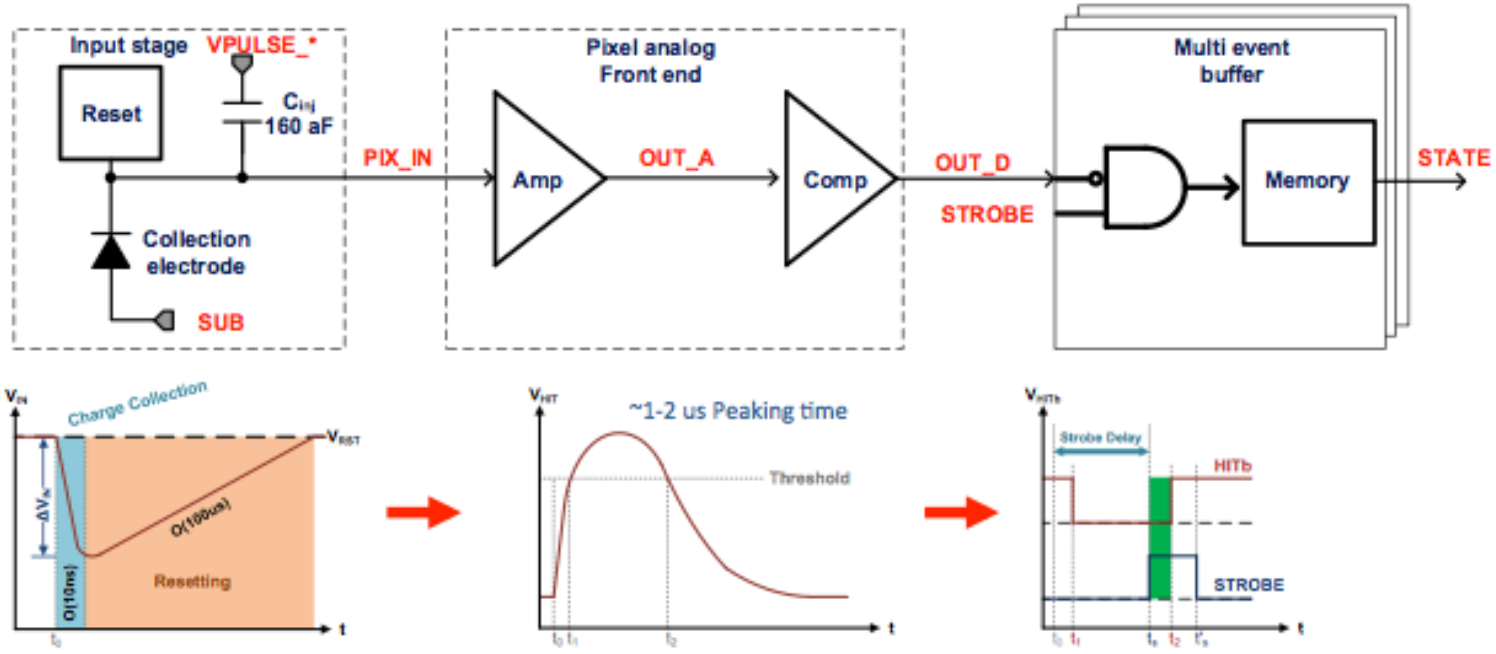
- 48 RUs
- 24 CRUs

sPHENIX: 48 +40% = 68

ITS IB:
Produce 120 staves in one year

120% contingency

ALPIDE Operation

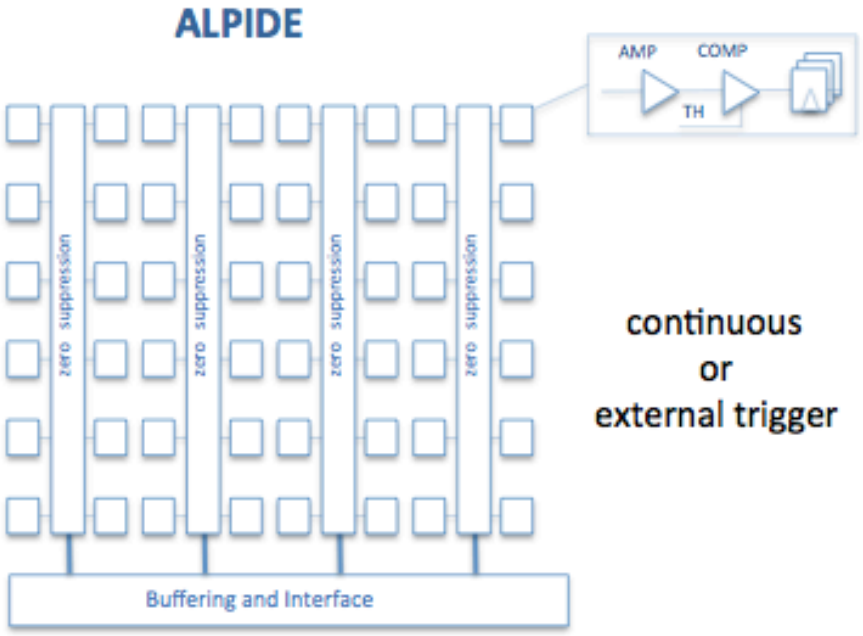


ultra low-power front-end circuit
40nW / pixel

Front-end acts as delay line

- Sensor and front-end continuously active
- Upon particle hit front-end forms a pulse with ~1-2µs peaking time
- Threshold is applied to form binary pulse
- Hit is latched into a (3-bit) memory if strobe is applied during binary pulse

ALPIDE Readout



continuous
or
external trigger

Architecture

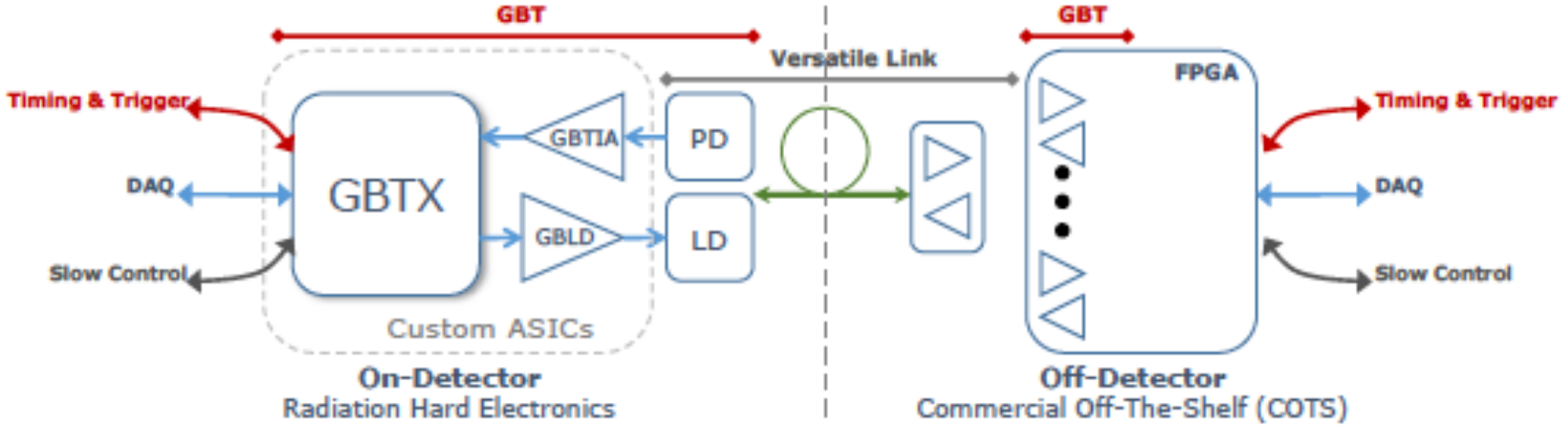
- In-pixel amplification
- In-pixel discrimination
- In-pixel (multi-) hit buffer
- In-matrix sparsification

Key Features

- 28 μm x 28 mm pixel pitch
- Continuously active, ultra-low power front-end (40nW/pixel)
- No clock propagation to the matrix → ultra-low power matrix readout (2mW whole chip)
- Global shutter (<10μs): triggered acquisition or continuous

Jo Schambach

GigaBitTransceiver (GBT)



Development of an high speed bidirectional radiation hard optical link:

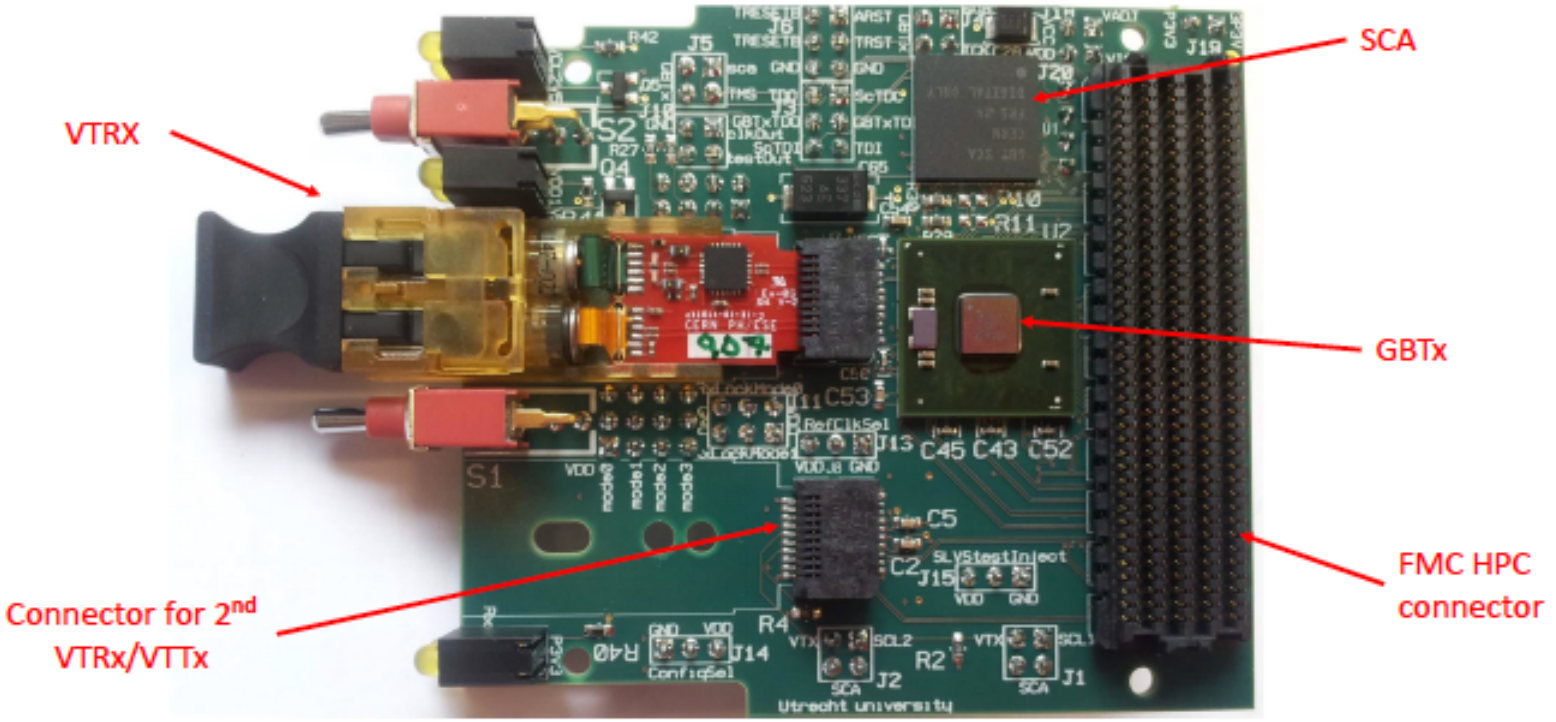
- *GBT project:*
  - ASIC design
  - Verification
  - Functionality testing
  - Packaging
- *Versatile link project:*
  - Opto-electronics
  - Radiation hardness
  - Functionality testing
  - Packaging

- The GBTX supports three frame types:
  - *"GBT" Frame (3.28 Gb/s user bandwidth)*
  - *"Wide Bus" Frame (3.52 Gb/s)*
  - *"8B/10B" Frame (4.48 Gb/s)*
- GBT Frames include "Forward Error Correction"

GBT Optic Transceiver Daughterboard for Readout Unit

From Pat McGaughey

GBT FMC Mezzanine ("GBTxFMC")

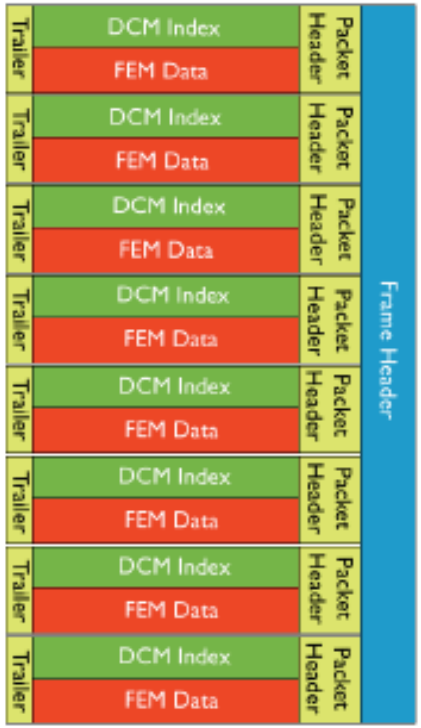


Low risk, tested and operational order for LANL in process

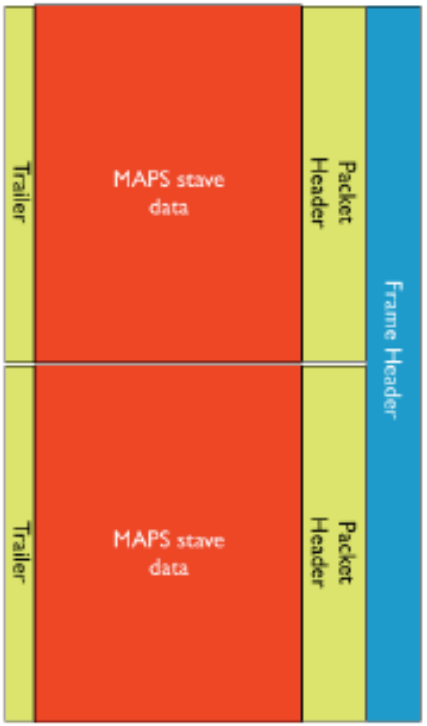
Data Formatting

From Mike McCumber

Traditional sPHENIX Frame



sPHENIX MAPS Common Readout Frame



Reformat options: FPGA or CPU…

(a) PCie40.

ALICE Format Data

Transport Headers and Trailers