MAPS-based Vertex Detector (MVTX)

WBS 1.13 (Full Detector) & 1.3 (Telescope)

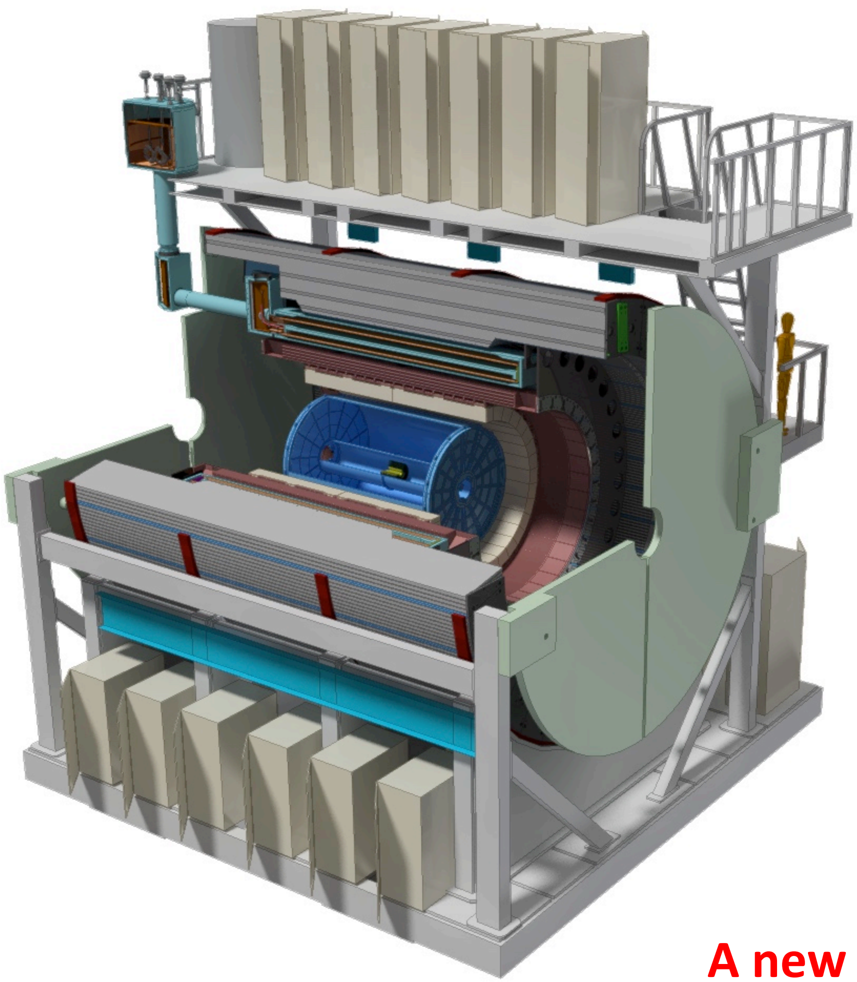
Ming Liu

1/23/2017

Outline

- Introduction
  - MAPS-based Vertex Detector (MVTX)
  - WBS and Baseline
- Project scope and schedule
- Tasks and collaboration
- MIE status and plan

WBS of the Baseline sPHENIX MIE



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

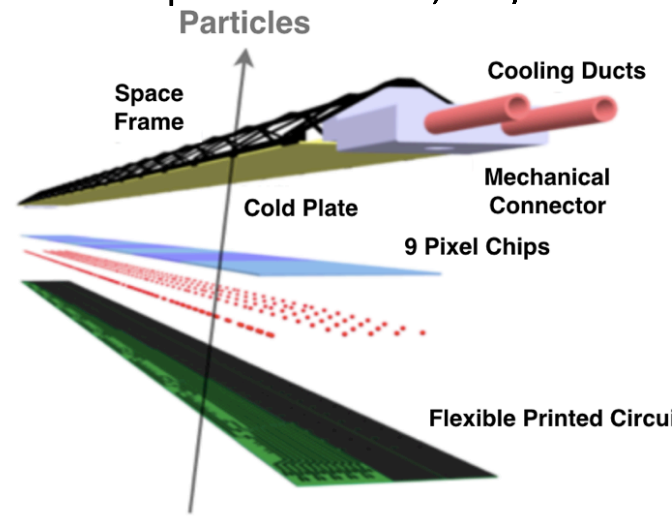
A new DOE MIE to build the full MAPS-based vertex Detector defined in the sPHENIX Reference Design

Monolithic-Active-Pixel-Sensors (MAPS)

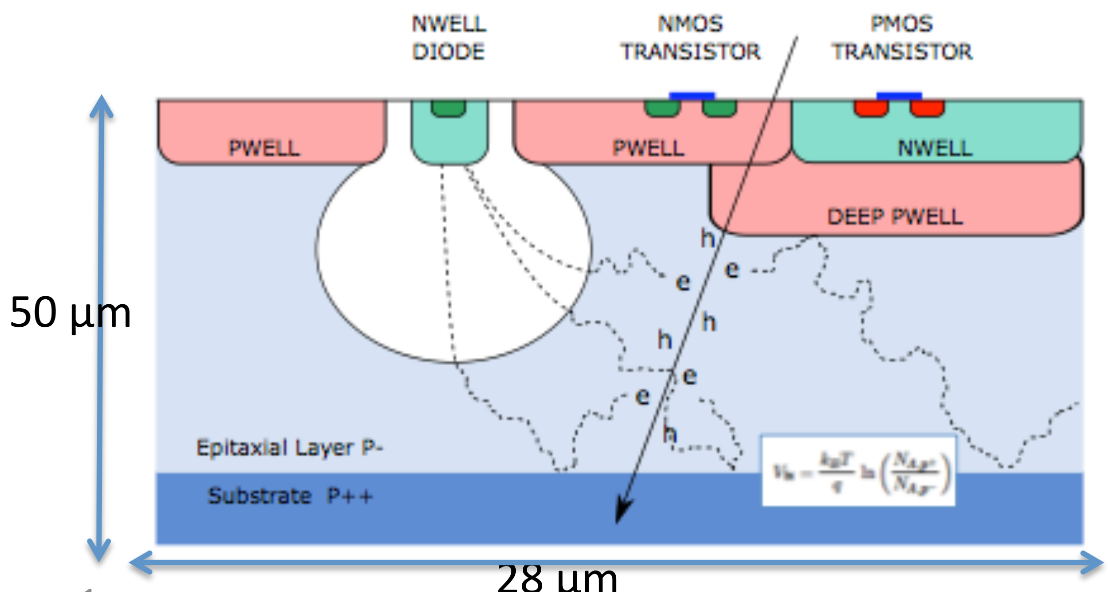
A State of the Art Tracker

- Advantages of MAPS:
  - Very fine pitch (28x28 µm)
  - High efficiency (>99%) and low noise ($<10^{-6}$)
  - Fast readout, 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!



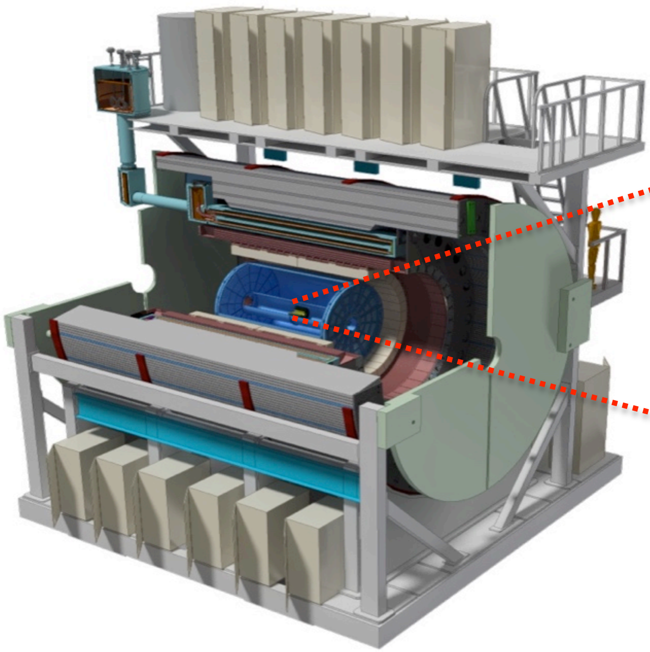
ALPIDE design

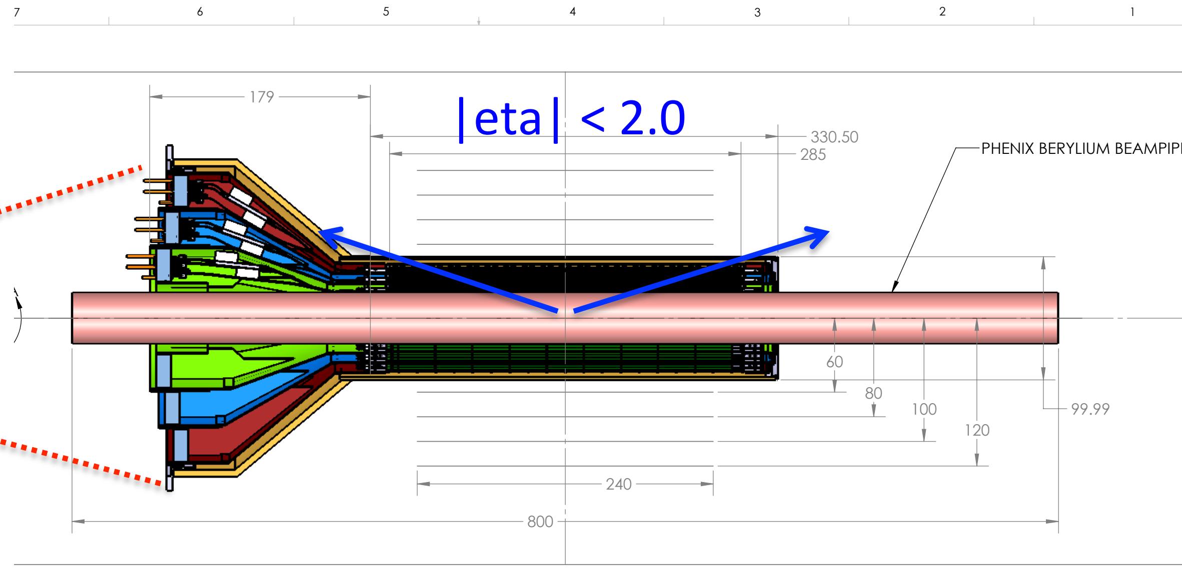
Tower Jazz 0.18 µm CMOS

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

sPHENIX MAPS-based Vertex Detector (MVTX)



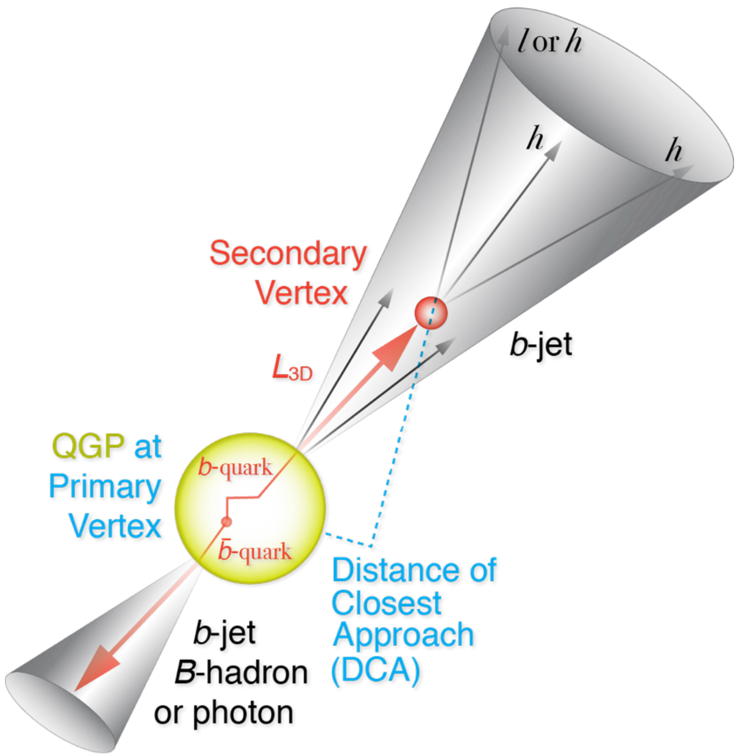


R = 2.4; 3.2; 3.9cm;
L = 27.1cm

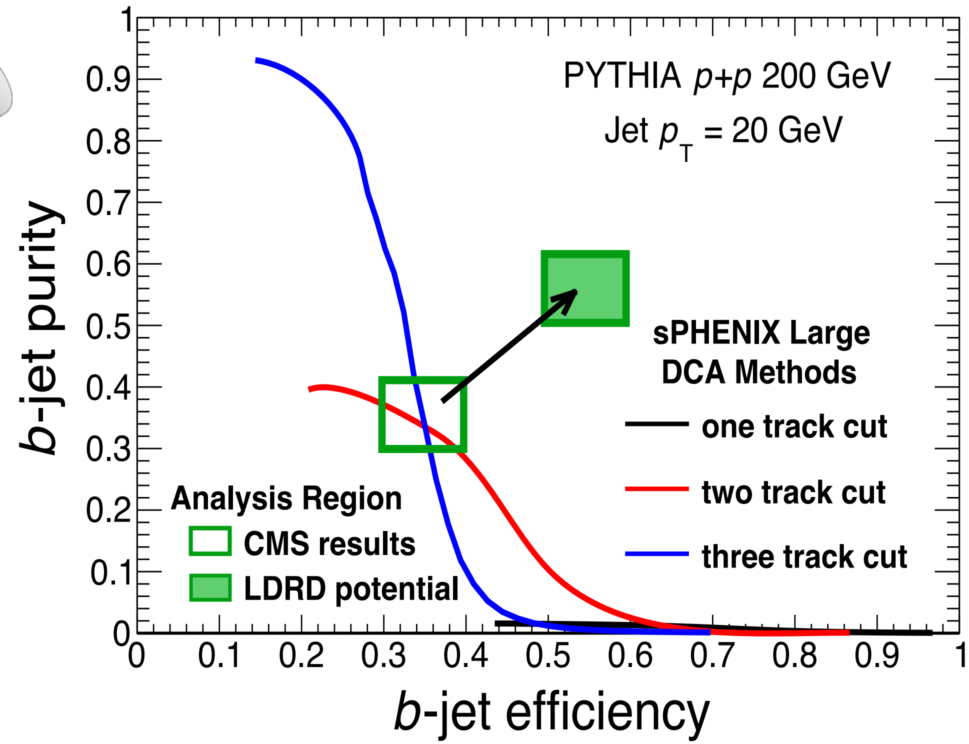
- "Adopt" ALICE ITS Upgrade Inner Barrel 3-layer MAPS detector
  - Mini. risk, Max. Physics
- Precision vertexing for b-jet/B-hadron tagging with high efficiency and high purity
- Study b-jet modification in QGP at low-medium pT to best determine QGP properties, collisional vs radiative energy loss, heavy quark flow etc.
- A separate DOE MIE for the full detector, WBS 1.13, ~$5M for construction
- Early R&D by LANL/LDRD, $5M, FY17-19, for readout and mechanical integration; recycle staves and electronics for WBS 1.3 Telescope

B-jet/B-hadron Tagging in sPHENIX

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)

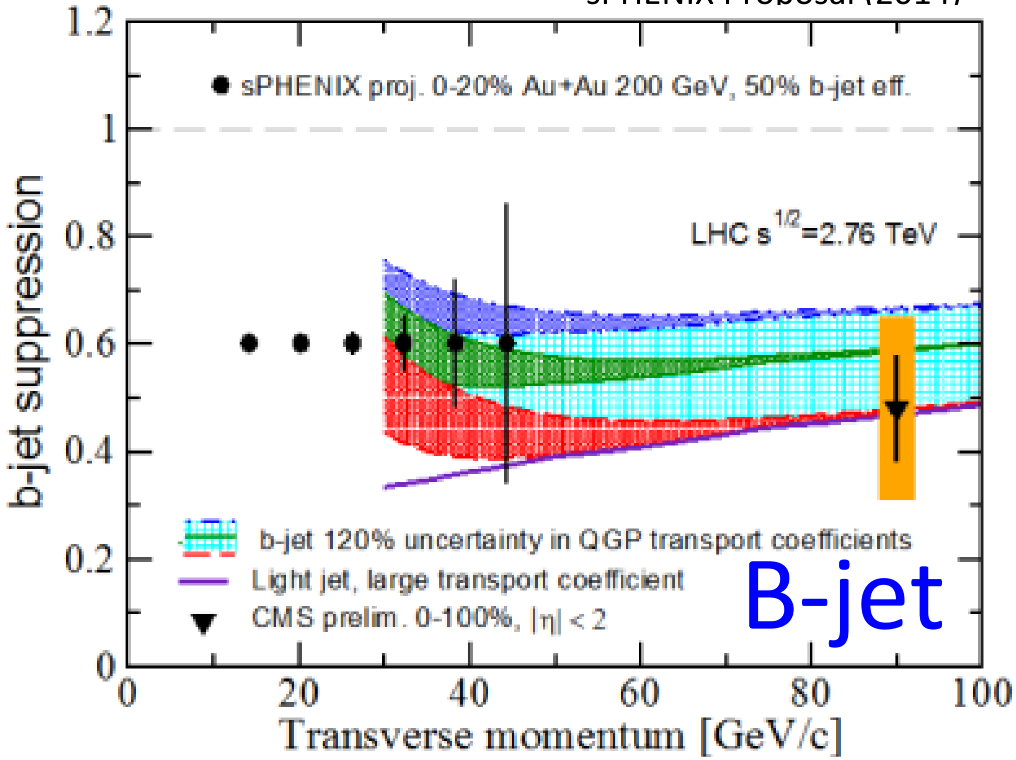
Jin, Xin, Cesar, Haiwang et al

Heavy Quark and QGP Interactions

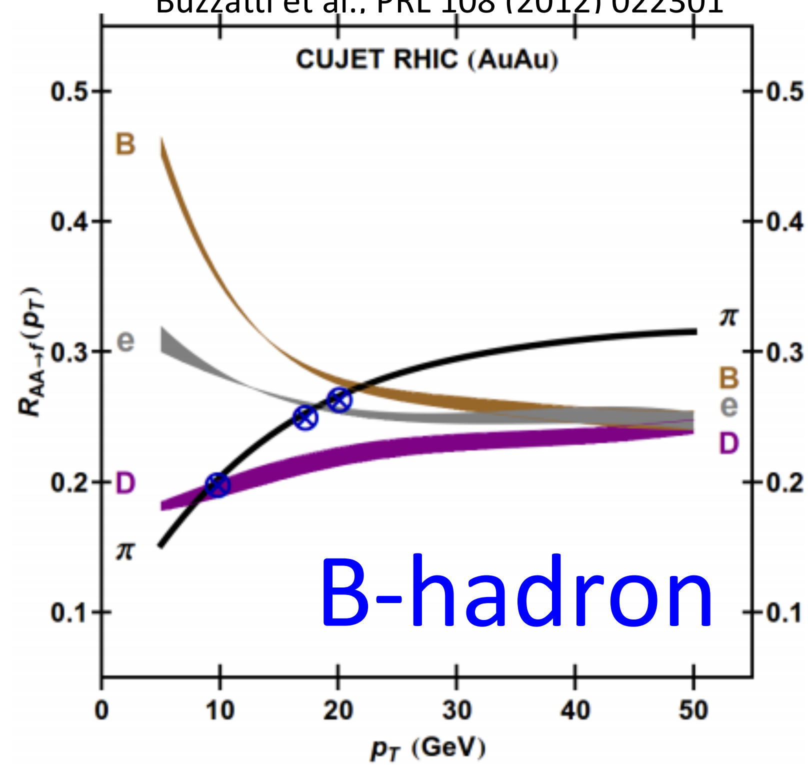
"Jet flavor tomography"

- B-jet modification, collisional vs radiative dE/dX, mass-dependence etc.
- Heavy quark flow, thermalization, recombination etc.

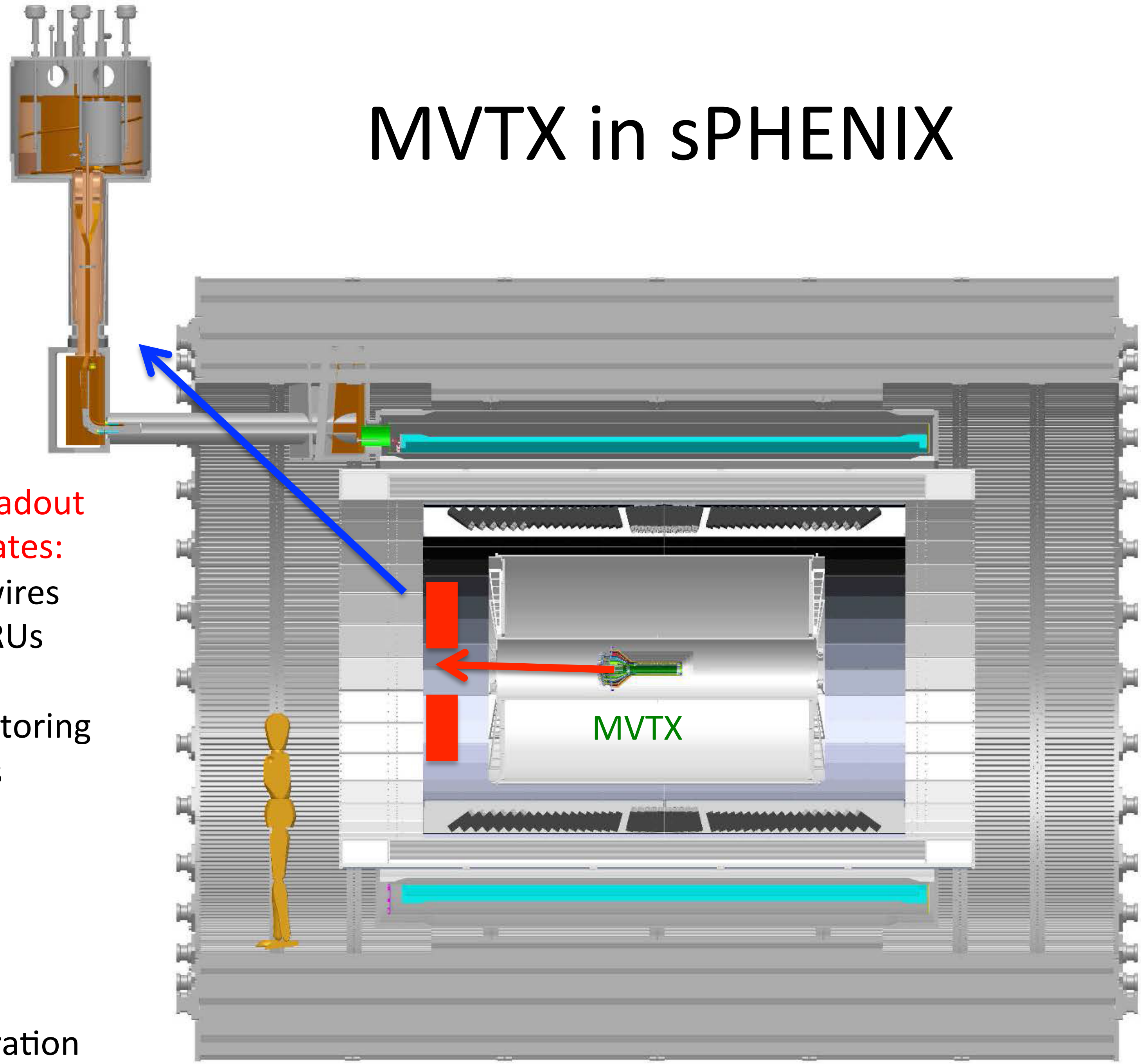
sPHENIX Proposal (2014)



Buzzatti et al., PRL 108 (2012) 022301



MVTX in sPHENIX



From MVTX to Readout Unit & Control Crates:

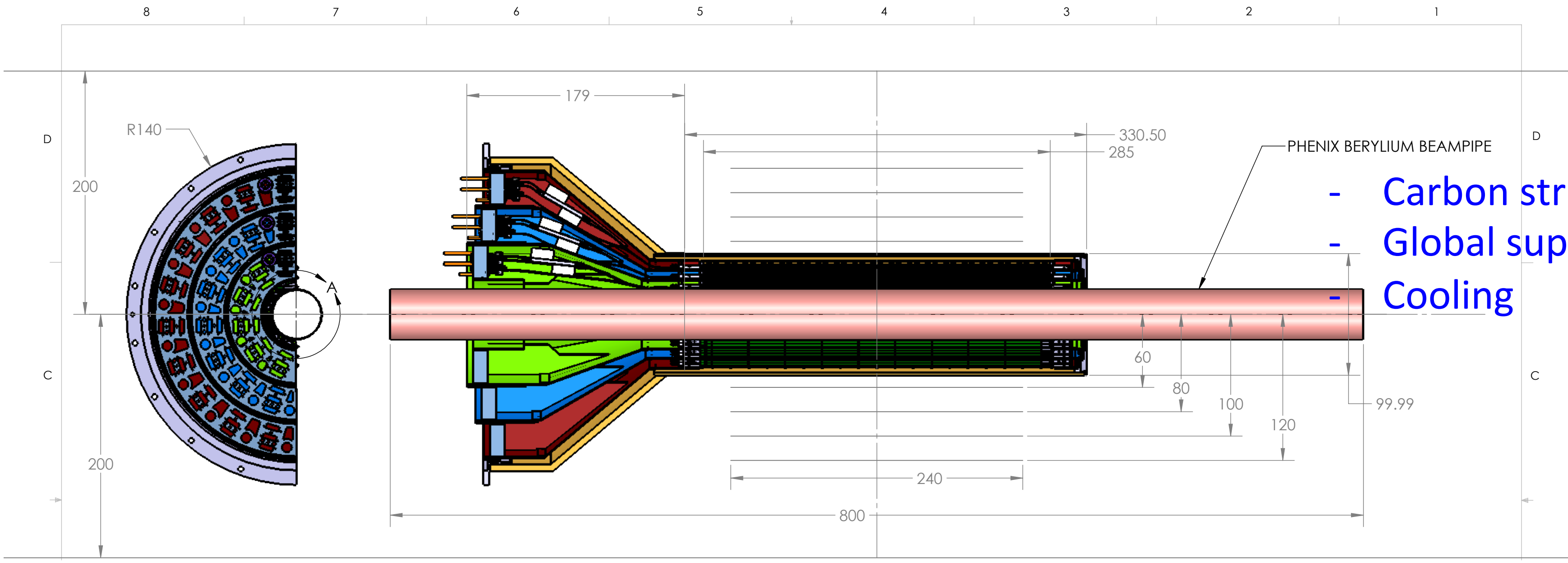
- "5m" copper wires
- Host 6U VME RUs
- Services for 48 modules, monitoring
- LV/HV controls

RU->CRU @CH:

- sPHENIX CRU
- Power supply
- 30+m fibers

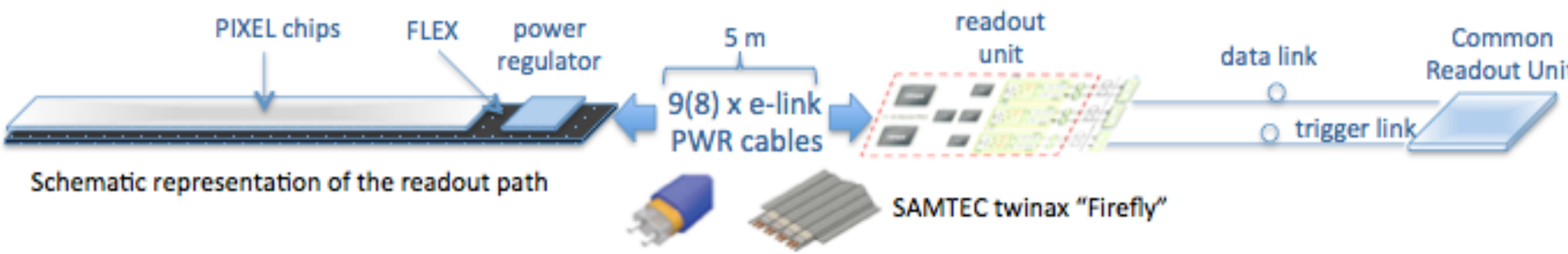
Mechanical Integration

MVTX-sPHENIX Integration



- Carbon structure
- Global support
- Cooling

Readout Chain: 48 staves – Readout Unit (IR) – Comm. Readout Unit (sPHENIX CH)



Scope of the MVTX Project

- MAPS staves & 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
    - sPHENIX personnel help assembly and testing staves at CERN
    - Reproduce additional ALICE RU+CRU for sPHENIX
    - Final assembly and test in US
  - Ancillary systems, copy ALICE
    - LV, 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
    - 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

WBS 1.13: a new MIE fund the full MAPS Vertex Detector, ~$5M
WBS 1.3: a sPHENIX baseline 10-stave telescope demonstrator

Project Tasks and Timeline

FY2016 FY2017 FY2018 FY2019 FY2020 FY2021

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

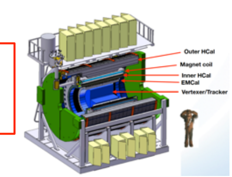
Readout R&D
Mech. design
@LANL/ALICE

Mech. Integr.
& Prototype
@MIT/LBNL

A schedule driven project!

Production

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



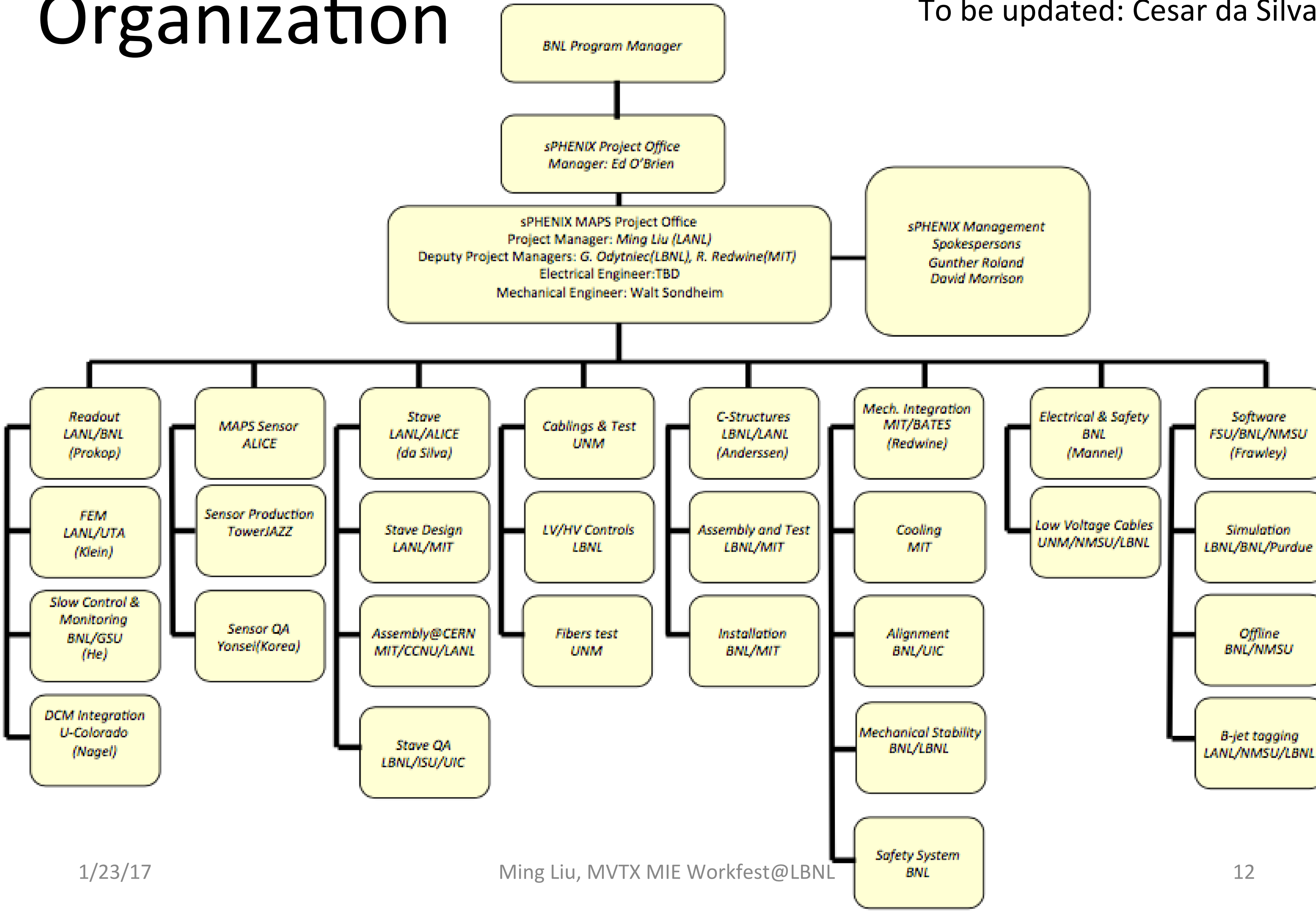
+2% +50%

"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 → **MVTX MIE**

More discussions:
Cesar, Gunther, Bob,
Giacomo, Grazyna et al

Organization

To be updated: Cesar da Silva



Project Cost and Schedule

To be updated: Dave Lee

Thu 1/19/17 MAPS_Inner_Barrel_Master-011817

ID	WBS	Task Name	Duration	Start	Finish	Institutic	calculate fixed cost	Cost	continger	Resource Cost	cost+contingen
1	1	**MAPS Inner Barrel**	**4073 days**	**Fri 10/21/05**	**Mon 6/21/21**		**$2,678,210.00**	**$5,946,494.00**		**$2,998,764.00**	**$6,605,684.50**
2	1.1	MAPS Inner Barrel Starts	0 days	Sat 10/1/16	Sat 10/1/16		$0.00	$0.00	0	$0.00	$0.00
3	1.2	MAPS Inner Barrel Ends	0 days	Tue 6/1/21	Tue 6/1/21		$0.00	$0.00	0	$0.00	$0.00
4	1.3	**Milestones & Key Tasks**	**0 days**	**Mon 10/3/16**	**Mon 10/3/16**		**$0.00**	**$0.00**	**0**	**$0.00**	**$0.00**
24	1.4	**LANL LDRD**	**1174 days**	**Mon 10/3/16**	**Wed 4/21/21**		**$365,500.00**	**$2,452,648.00**		**$1,831,148.00**	**$2,196,648.00**
105	1.5	**sPHENIX Project**	**4073 days**	**Fri 10/21/05**	**Mon 6/21/21**		**$2,312,710.00**	**$3,493,846.00**		**$1,167,616.00**	**$4,409,036.50**
106	1.5.1	**sPHENIX Project Management**	**1231 days**	**Tue 9/13/16**	**Mon 6/21/21**	**LANL**	**$0.00**	**$126,568.00**		**$126,568.00**	**$139,224.80**
110	1.5.2	**Electronics**	**319 days**	**Thu 4/20/17**	**Thu 7/26/18**	**LANL**	**$25,000.00**	**$82,664.00**		**$57,664.00**	**$105,893.20**
120	1.5.3	**Mechanics**	**3384 days**	**Fri 10/21/05**	**Tue 10/30/18**		**$100,000.00**	**$397,936.00**		**$284,416.00**	**$488,502.00**
150	1.5.4	**MAPS Inner Barrel Review**	**12 days**	**Fri 6/1/18**	**Mon 6/18/18**		**$0.00**	**$14,560.00**		**$14,560.00**	**$16,016.00**
154	1.5.5	**Final System Test**	**90 days**	**Fri 4/21/06**	**Thu 8/24/06**		**$50,000.00**	**$103,640.00**		**$53,640.00**	**$129,550.00**
156	1.5.6	**Procurements**	**500 days**	**Wed 8/1/18**	**Tue 6/30/20**	**LANL**	**$2,137,710.00**	**$2,518,078.00**		**$380,368.00**	**$3,228,802.50**
186	1.5.7	**Installation**	**131 days**	**Wed 7/1/20**	**Wed 12/30/20**		**$0.00**	**$250,400.00**		**$250,400.00**	**$301,048.00**
191	1.5.8	Ready for beam	0 days	Wed 12/30/20	Wed 12/30/20		$0.00	$0.00	0	$0.00	$0.00

Status of MIE

- Thanks for all the hard work put in by everyone!
- First draft of proposal narrative available, about 21 pages
- Some sessions are more complete than others
- Need input from each institution
  - FTE
  - Labor rates
  - Resource schedule
  - Focus area
- Further editing /polishing

Table of Contents

Plan for next 2 days

- Presentation and discussion for each session
- Update them with the latest information
- Proofreading and polishing

To be ready for submission to DOE, 2 weeks before the Feb. budget meeting (2/15 for LANL)

Targeted submission date: Feb 1, 2017 (Wed.)

Jan 24, Perseverance Hall Main Room

9:00-9:10	Welcome	Barbara Jacak
9:10-9:25	sPHENIX status	Gunther Roland / Dave Morrison
9:25-10:00	MAPS pre-proposal overview	Ming Liu
10:00-10:30	Cost and schedule	David Lee
10:30-11:00	Coffee Break	
11:00-11:30	Organization, b-physics goal	Cesar da Silva
11:30-12:00	b-tagged jet physics	Jin Huang
12:00-12:30	B-meson physics	Xin Dong / Xiaolong Chen
12:00-14:00	Lunch break	
14:00-14:30	MAPS chips/stave production	Ming Liu / Cesar da Silva
14:30-15:00	Inner tracker overview, LV/HV PS controls, carbon fiber structure	Giacomo Contin
15:00-15:30	Mechanical integration	Walter Sondheim / Bob Redwine / Grazyna Odyniec
15:30-16:00	Coffee Break	
16:00-16:20	MAPS staves assembly and testing at CERN	Gunther Roland
16:20-16:40	Full module assembly and test in US	Giacomo Contin
16:40-17:00	Online software/trigger	Xiaochun He
17:00-17:20	Offline software, simulation, geometry, tracking	Haiwang
17:20-17:30	Purdue silicon lab facilities	Wei Xie
18:00	Dinner	

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Editing/Proofreading
– Dennis, Darren, Hubert et al

1. Ming, Mike, Gunther et al

2. Cesar, Xin et al

3. Jin, Darren, Haiwang et al

4. Giacomo et al

5. Tony, Haiwang, Jin et al

6.1 Cesar, Mike, Ming,
6.2 Grazyna/Leo, Ming et al
6.3 Walt, Grazyna/Eric et al
6.4 Bob, Gunther, Walt
6.5 Grazyna/Leo et al
6.6 Gunther etal
6.7 Grazyna/Leo
6.8 Xiaochun, Chris et al
6.9 Tony, Jin, Chris et al

7. Cesar, Gunther et al

8. Dave, Ming et al

Backup slides

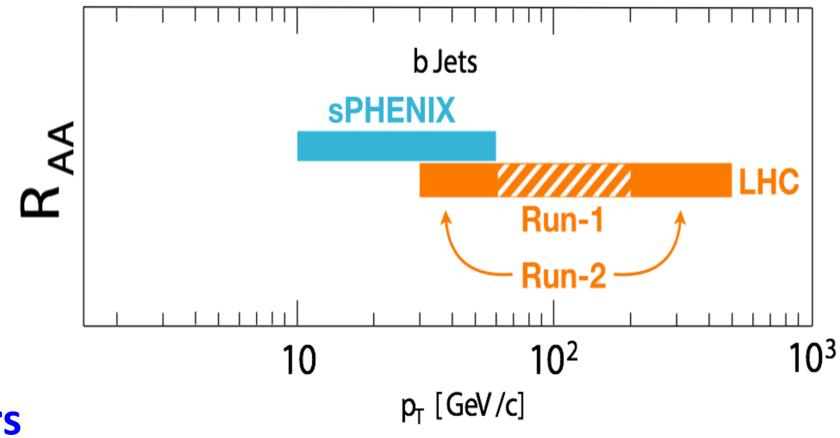
Vertex Detector Design Drivers

- **Inner Silicon tracking driven by heavy flavor jet performance**
- Track acceptance: $-1.1<\eta<+1.1$ and $0<\phi<2\pi$
- Minimum vertex acceptance: -10 cm $< z_{vtx} < +10$ cm
- Meet or Exceed a 30% b-jet efficiency at 30% b-jet purity
  - defined by the CMS of b-jet figure-of-merit
- Minimum track efficiency: >95% of all charged particles
- Minimum DCA_{XY} resolution: < 70 microns
- Resolve multiple collisions vertexes at large collider luminosities
- Maintain track momentum resolution:
  - Upsilon mass: dp/p <1.2% for $4 < p_T < 10$ GeV/c
  - Jet Fragmentation: dp/p < (0.2% x p) for $p_T < 40$ GeV/c
- Maintain small rate of tracking ambiguities: *fake tracks*

Exciting Science: Physics of the 3rd Pillar

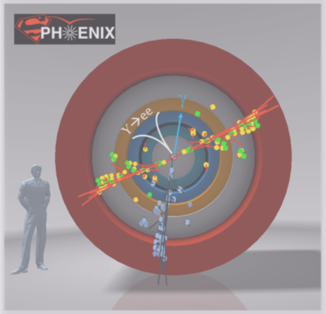
- sPHENIX is the next flagship heavy ion physics experiment in US
  - Jets
  - Upsilons
  - B-jets
- MVTX will complete b-jet physics

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

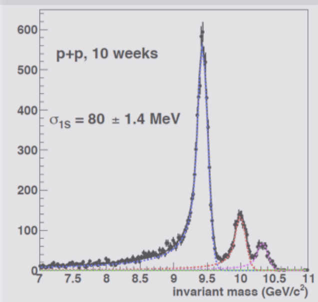


sPHENIX Three Physics Pillars

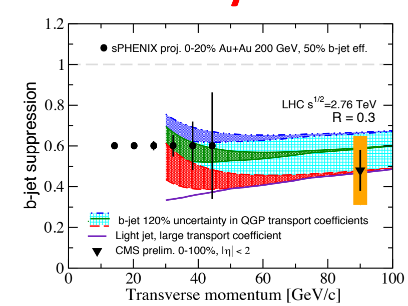
Jets



Upsilons

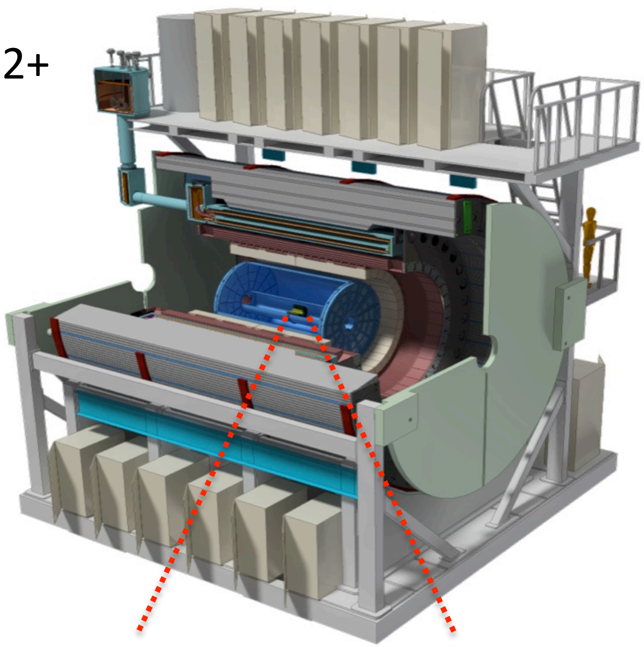


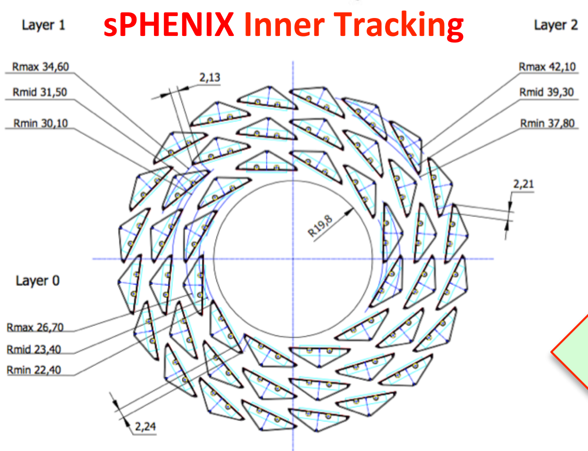
B-Jets Physics



Proposed sPHENIX MAPS-based Vertex Detector (MVTX)

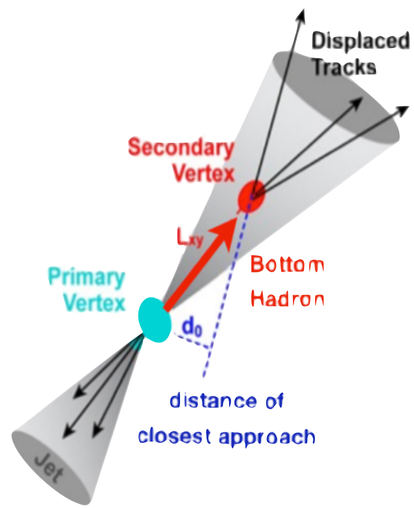
2022+



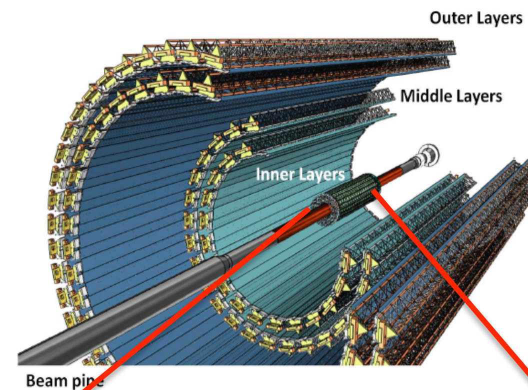


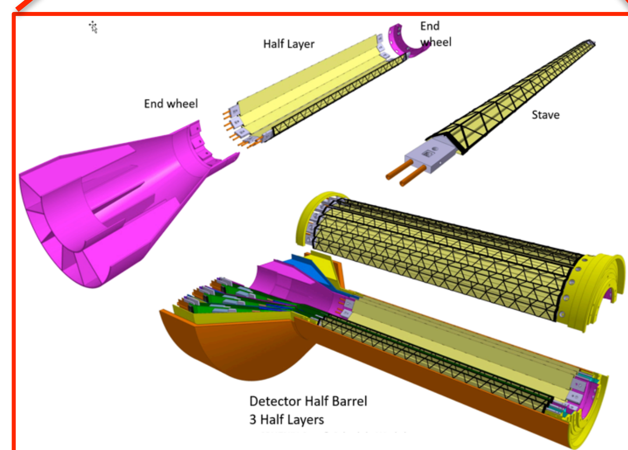
sPHENIX Inner Tracking

Key issues:
- Readout
- Mechanics



ALICE ITS Upgrade (2021+);
Inner Tracker System



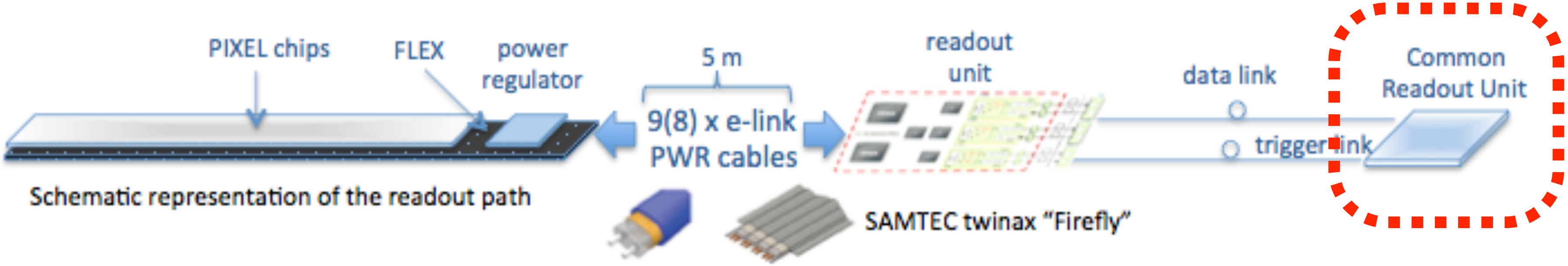


"Adopt" ALICE/ITS
Mini. risk,
Max. physics

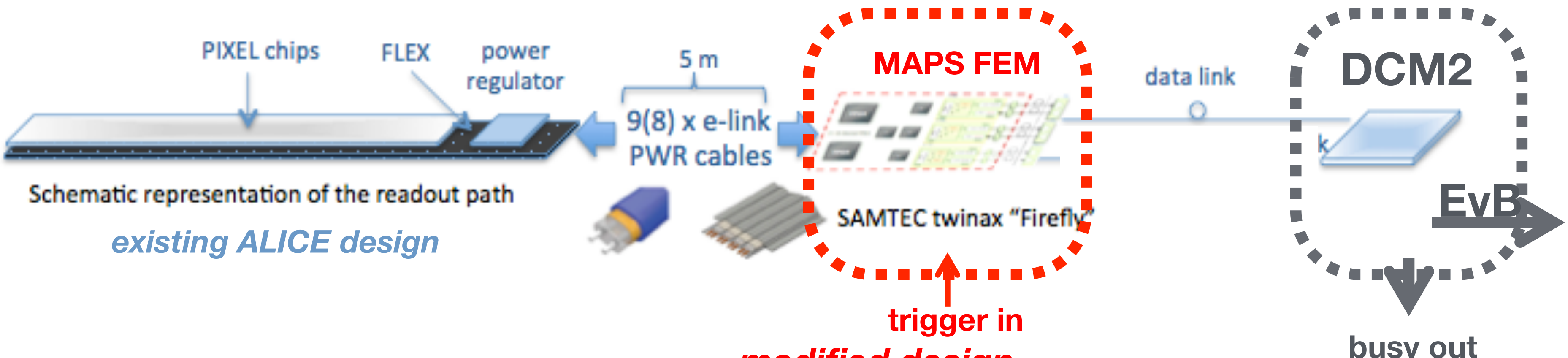
MAPS-sPHENIX Electronics Integration

Plan A: reprogram

ALICE readout path



Plan B: sPHENIX readout path (held as contingency)



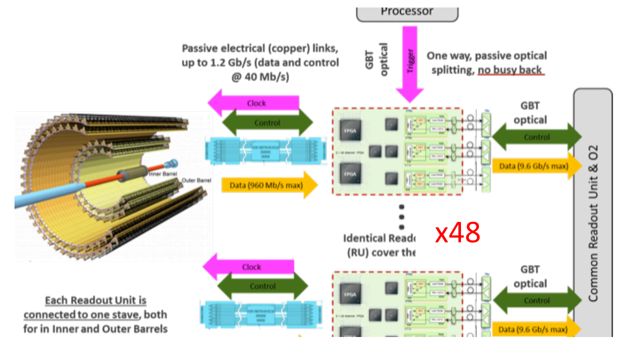
modified design, starting with ALICE boards

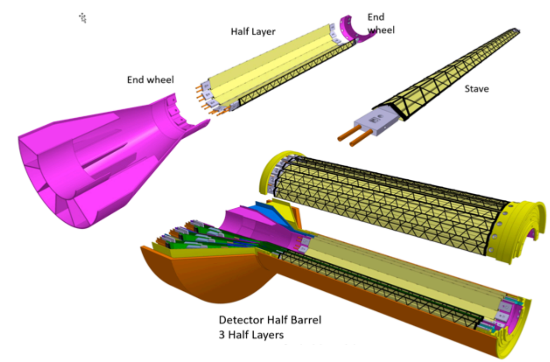
existing sPHENIX design

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 design
  - FVTX/PHENIX and HFT/STAR experience





CD-1 Practice Speaker Instructions

CD-1 Review Speaker Instructions:

Include the following slides:

15 slides:

- **1-2 slides describing the system.** Include a figure of the system, performance specs, design specs, physics contribution if appropriate to the subsystem.
- **1 slide with a brief technical overview.** List the design drivers.
- **1 slide defining the scope of the subsystem.** Channel counts, segmentation, coverage, etc.
- **1 Interface slide** listing the mechanical and electronics boundaries of the system. Text list of what is "inside the L2 scope " and what is "outside the L2 scope" with an indication of what WBS contains the "outside the L2" and what is existing from PHENIX.
- **1 slide** showing the **WBS structure** and th**e Control Accounts.**
- **1 slide listing the L2 and CAMs by name and Institutions** with a brief description of their experience
- **1 slide** showing **schedule drivers,** a schedule Gantt chart and a list of milestones that include design reviews, prototype v_x complete, PRR, production starts, production ends, installation.
- **1 slide for the budget with OPC, EQUMIE profile (capital equipment) in AY$.** Include a list of 5-10 major cost items on this slide, the cost drivers.
- **1 slide with the labor profile broken down by job category.** Identify the labor you have, and the labor that you still need to identify.
- **1 slide for the status of the design** (off project)**, generic R&D** (off project) if any and **OPC**
- **1 slide** showing **WBS dictionary**
- **1 slide** showing BOE
- **1 slide** showing **Risk analysis**
- **1 slide** listing **Issues and Concerns**
- **No summary**