

# MAPS Cost, Schedule and Resources Plan

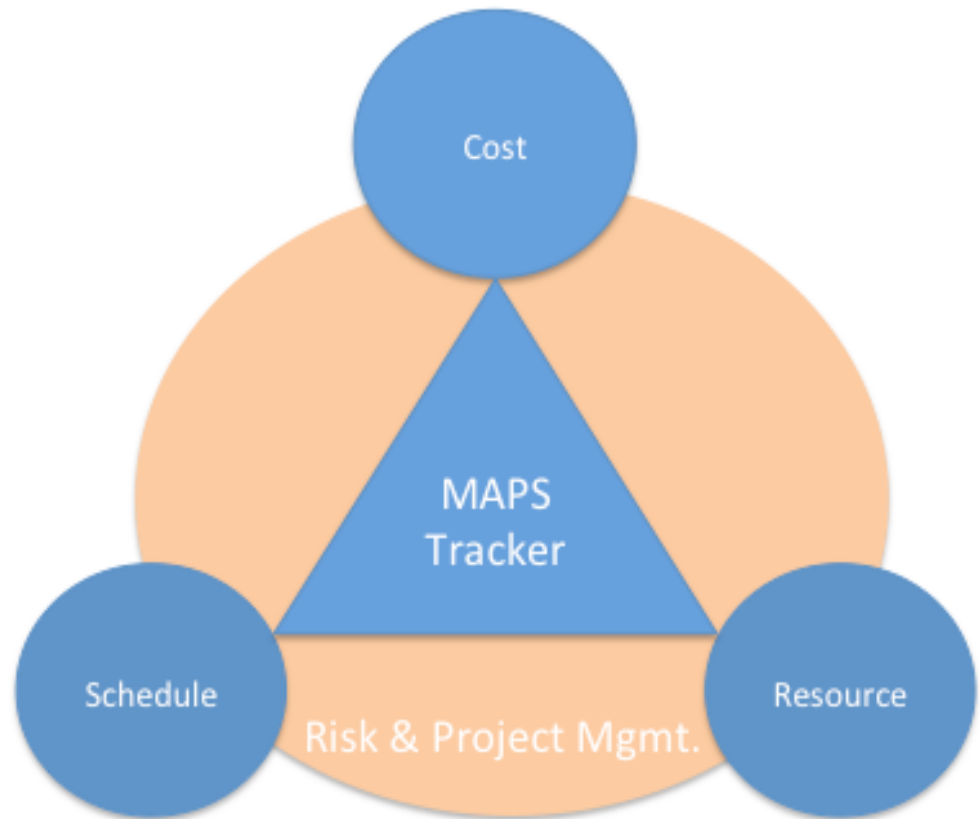
Ming Liu

Los Alamos National Laboratory

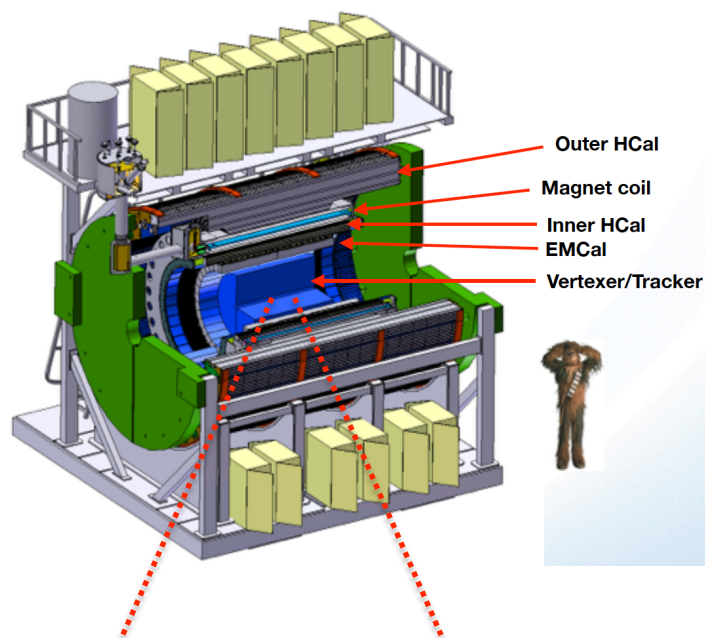
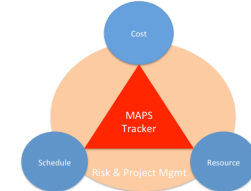
Sept. 7, 2016

# Outline

- Scope of project
  - MAPS inner tracker
  - Cost and Schedule Basis
- Cost
  - R&D
  - Production
- Schedule
  - R&D
  - Production
- Resources
- Risk and project management



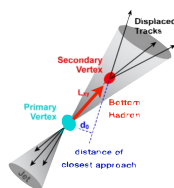
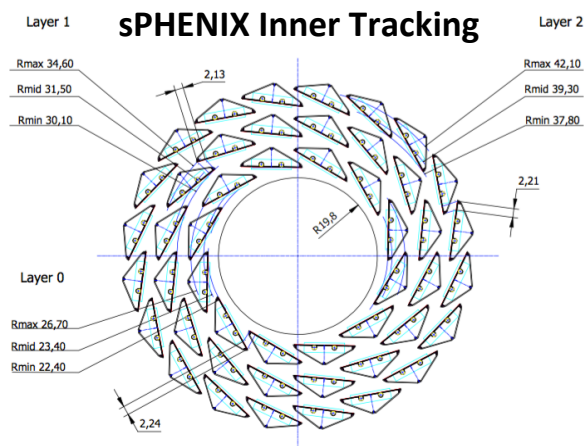
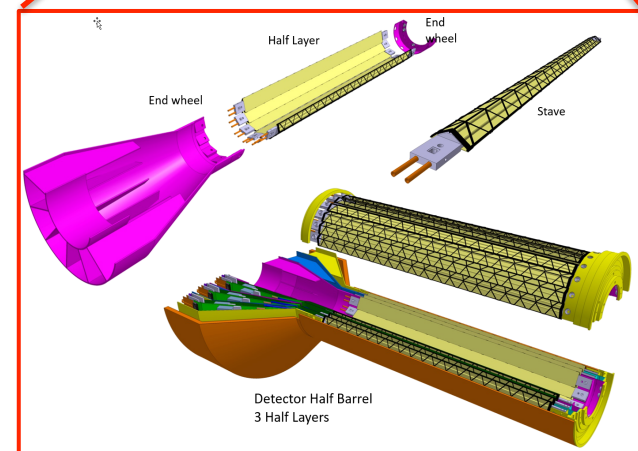
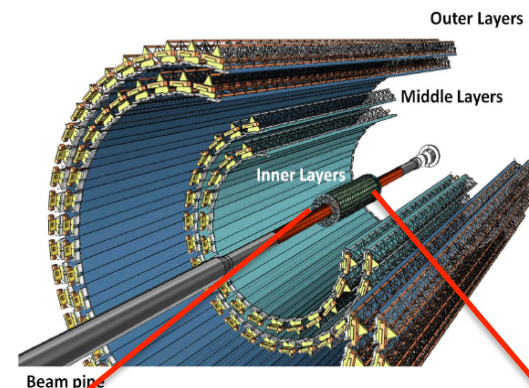
# sPHENIX MAPS Inner Tracker



*Key issues:*

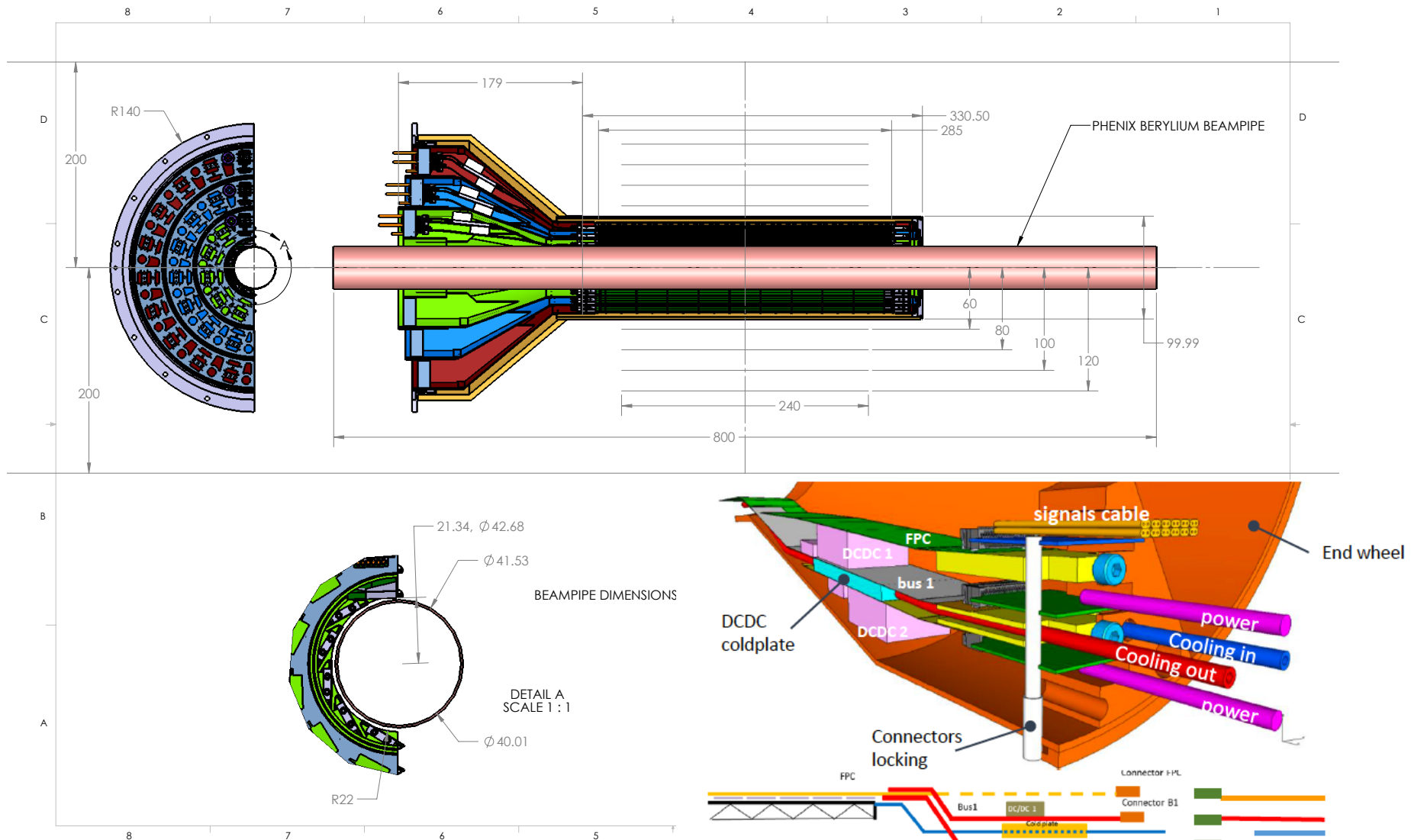
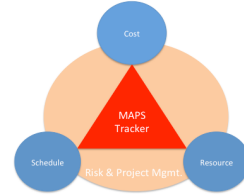
- Readout
- Mechanics

ALICE ITS;  
Inner Tracker System



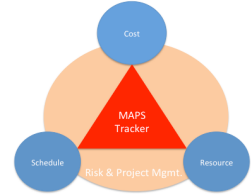
Copy of ITS  
Inner Tracker

# sPHENIX MAPS Inner Tracker





# Scope of the Project

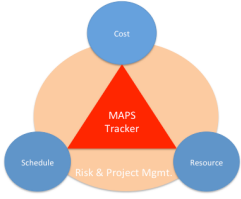


- **MAPS & Electronics**

- MAPS Detectors
  - MoU to build 68 ITS MAPS staves
  - No modification
- Readout Electronics
  - Use ALICE/ITS, RDO + 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 RDO+CRU for sPHENIX
- Ancillary systems
  - 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
- Mechanics Integration
  - Conceptual design by LANL LDRD
  - Prototype by sPHENIX R&D
  - Design integration frames
  - Cage etc.
  - Installation tooling etc.
- Copy ALICE cooling plant design
  - Minor modification to fit sPHENIX
  - Smaller heat load than ALICE ITS
- Metrology and Survey

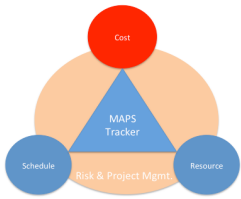


# Assumptions

- Copy ALICE 3-layer MAPS Inner Tracker
  - Extend ALICE ITS production
  - Follow proposed sPHENIX CD process
  - Critical R&D by LANL LDRD
  - Mechanical Integration R&D fund available for CD-2/3
  - Production starts at CD-3b
- 
- Initial cost and schedule from ALICE ITS documents
  - Other cost from recent experiments, FVTX/PHENIX, HFT/STAR
  - Labor costs from Lab Engineers and Techs
  - Durations from ALICE C&S where available, FVTX/PHENIX experience
  - Schedule contingency in progress (MoU w/ ALICE, mortgage etc. )
  - Apply 40% cost & schedule contingency (pre CD-0)
  - Initial cost and manpower allocation, w/o funding profile

# MAPS Cost and Schedule Workshop

## 3/30-4/1, 2016, Santa Fe, NM



<https://indico.bnl.gov/conferenceDisplay.py?confId=1741>

Well attended by experts from:  
sPHENIX, ITS/ALICE,  
HFT/STAR, FVTX/PHENIX, EIC

LANL, CERN, LBNL, BNL, MIT, FSU, UColorado  
Yonsei/Korea, and several other US institutions

### Take Home:

- Extension of ALICE production possible
- Inner tracker cost <\$5M inc. contingency
- Can meet sPHENIX CD schedule



### sPHENIX MAPS Cost & Schedule Workfest

from 30 March 2016 to 01 April 2016 (US/Mountain) *El Dorado Hotel*  
US/Mountain timezone

Search

#### Overview

- Timetable
- Contribution List
- Author Index
- Registration
  - Registration Form
- List of registrants

[Organizers](#)

The purpose of this 3 day workfest is to define and document the cost and schedule for the MAPS based tracking options under consideration for the sPHENIX detector. The interactive workfest format will be organized into topical breakout teams with MAPS, engineering, and C&S experts we are gathering from ALICE, sPHENIX, and other projects and will minimize time spent in presentations.

Update 3/2/16: The workfest will be held at the El Dorado Hotel. The hotel is located just a short walk west of the historic downtown square. See <http://www.eldoradohotel.com> for more hotel details. We've arranged for a block of rooms is available now and can be booked at the workfest/gov't rate (\$99/night) if you follow: <https://gc.synxis.com/rez.aspx?Hotel=63150&Chain=17123&Dest=Santa+Fe&template=GCF&shell=GCF&locale=en-US&arrive=3/29/2016&depart=4/1/2016&adult=1&child=0&group=sPHENIX> which will lead you to a web form for the conference. If you decide to call the hotel directly at 505-995-4500, our call-in/group code for the reservations is: sPHENIX.

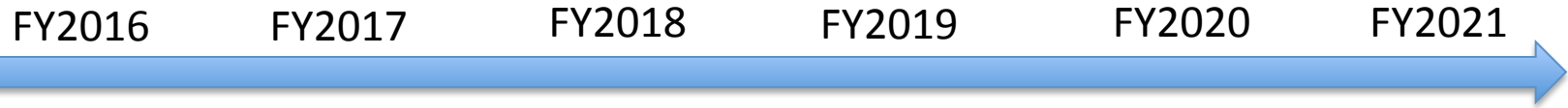
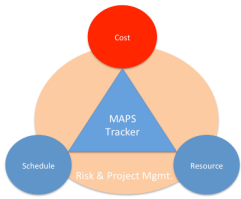
FAQ: *Should I fly out of ABQ on Friday evening or Saturday morning?*

The answer to this is if you can find a suitable flight or not. We expect that some participants will book flights out Friday evening and leave the workfest in the afternoon to take those flights. Not all participants will find a flight and so Saturday morning will be an option for them. Our plan is to be finalizing the C&S document on Friday afternoon. The organizers will stay until the end of the day and go to dinner with the remaining participants. The drive from Santa Fe to the airport (ABQ) will take approximately 1 hour.

**Dates:** from 30 March 2016 09:00 to 01 April 2016 17:30  
**Timezone:** US/Mountain  
**Location:** *El Dorado Hotel*  
309 W San Francisco St.  
Santa Fe, NM 87501  
Room: DeVargas  
**Material:** [Folder](#)  
[Slides](#)

- First draft Cost and Schedule project was produced based on inputs from Santa Fe Workshop
- Further inputs from BNL 6/30 MAPS mini review

# Project Task and Time Line

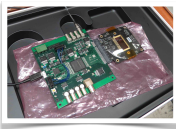


CD-0  
11/1

CD-1  
11/1

CD-2/3  
8/1

Ready for  
Beam  
6/1



Readout R&D  
Mech. design  
@LANL/ALICE

Key R&D

Mech. Integr.  
& Prototype  
@BNL/LANL

Production

MAPS Prod. & QA  
@ALICE

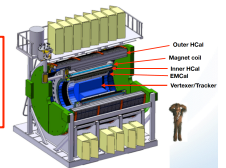
+2%

Stave Prod.&Test  
@CERN;  
FEM Prod. @US

+50%

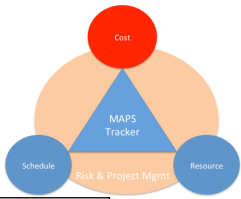
Det. Assembly & Test  
@BNL

Det. Install.  
@BNL



MoU w/ ALICE: 12/2016  
To produce staves, frames and FEMs

# Major Item Cost Estimate



|                                          |                   |                     |                             |                    |                             |                                                          |             |        |                                      |
|------------------------------------------|-------------------|---------------------|-----------------------------|--------------------|-----------------------------|----------------------------------------------------------|-------------|--------|--------------------------------------|
| 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 Contingency (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                                   |
| Mechanical 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

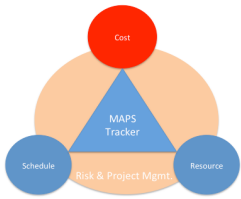
R&D Labor

Prod. M&S

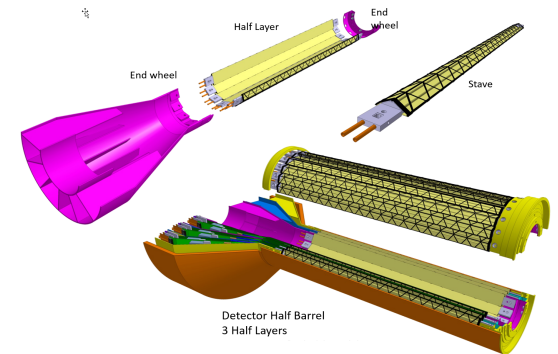
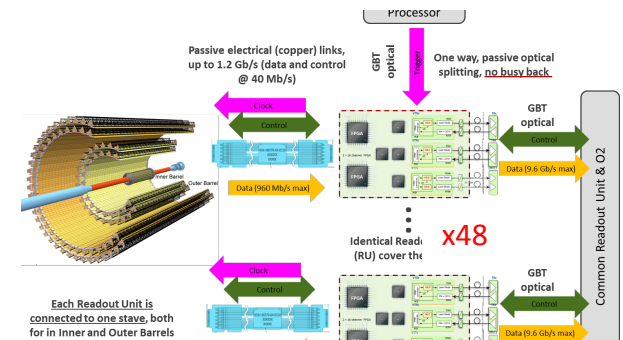
Prod. Labor

Pod. M&S with Cont. &  
OH

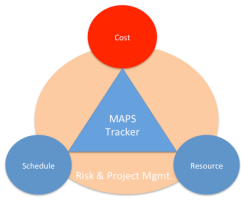
# Cost Basis – Major Items



- MAPS and Staves
  - ALICE ITS production
- Readout
  - ALICE ITS RDO 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 experience



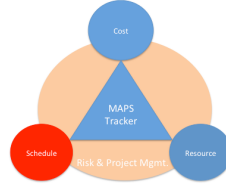
# Major Item Prototype Costs



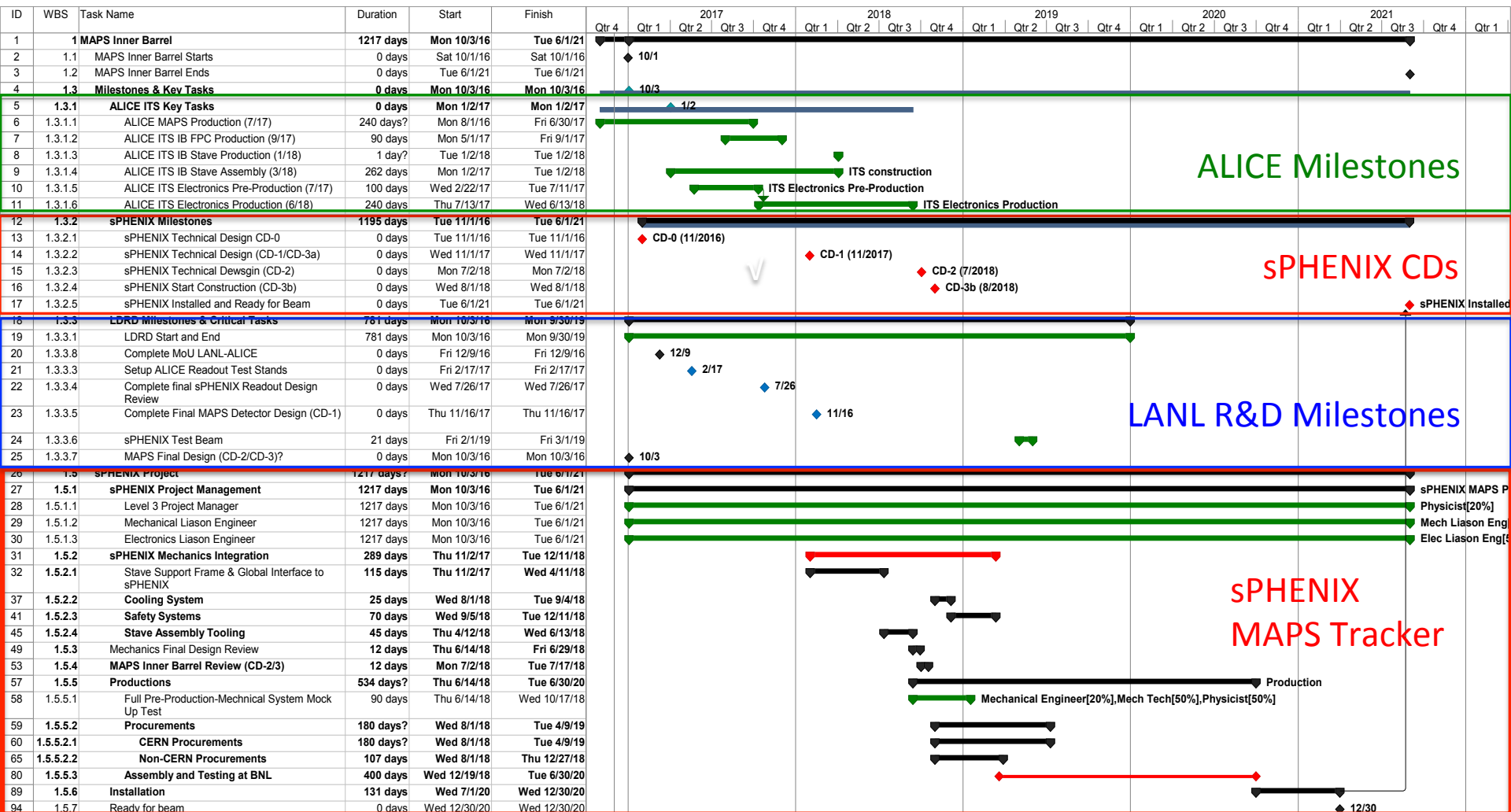
- LANL LDRD-DR: \$932K
  - \$1.1M/year for 3 years (FTE's and M&S )
    - DAQ Interface: \$605K
    - Mechanics: \$228K
    - Test beam: \$99K
- sPHENIX Prototype: \$273K
  - Mechanical design and integration: \$223K
  - Mechanical prototype: \$50K



# Overview of Schedules

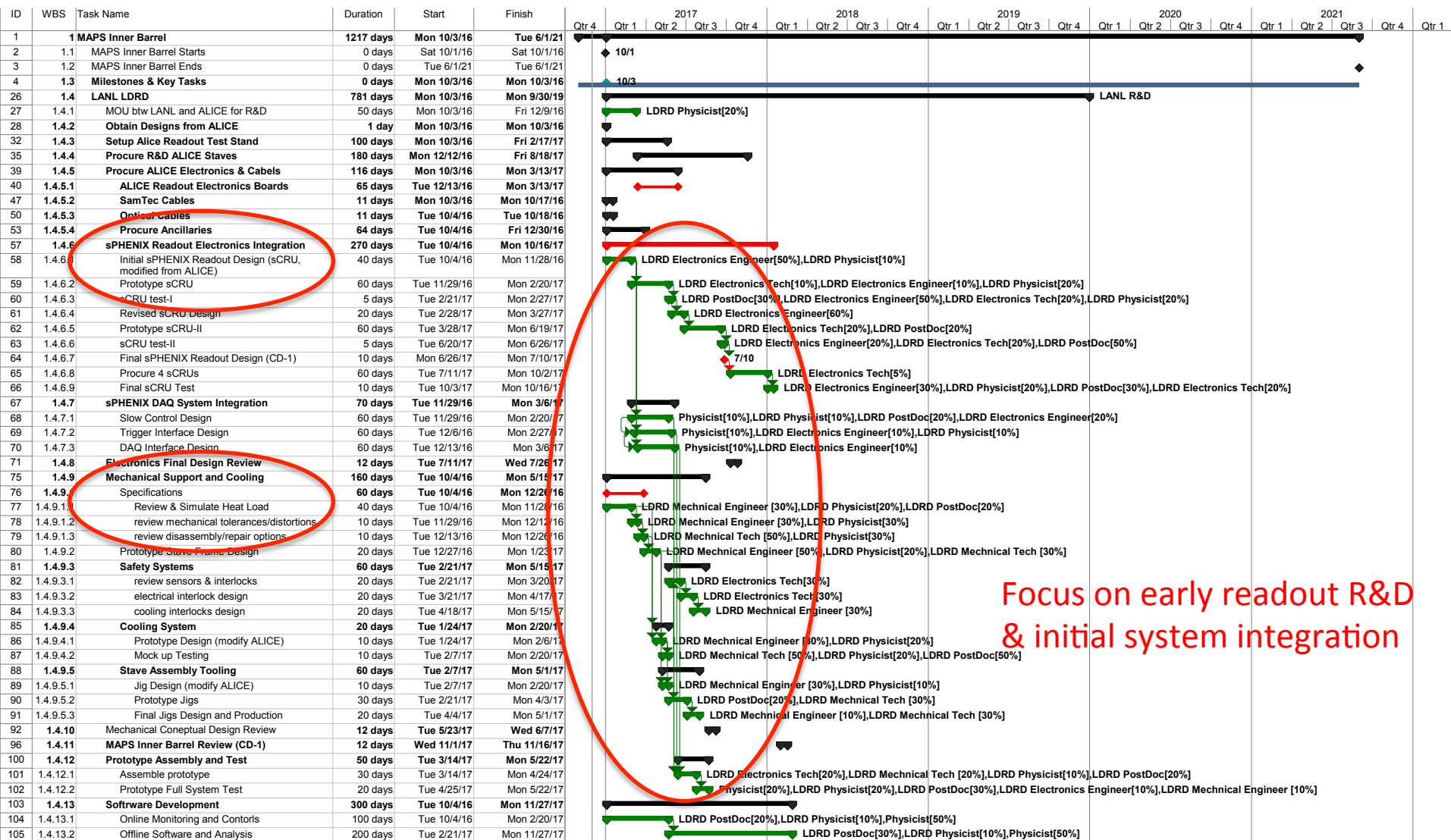
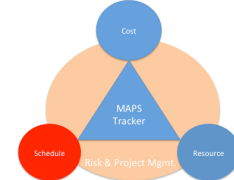


Thu 9/1/16



About 6 months of schedule float

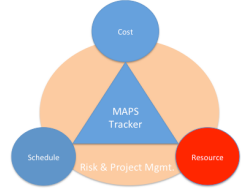
# LANL R&D Schedule



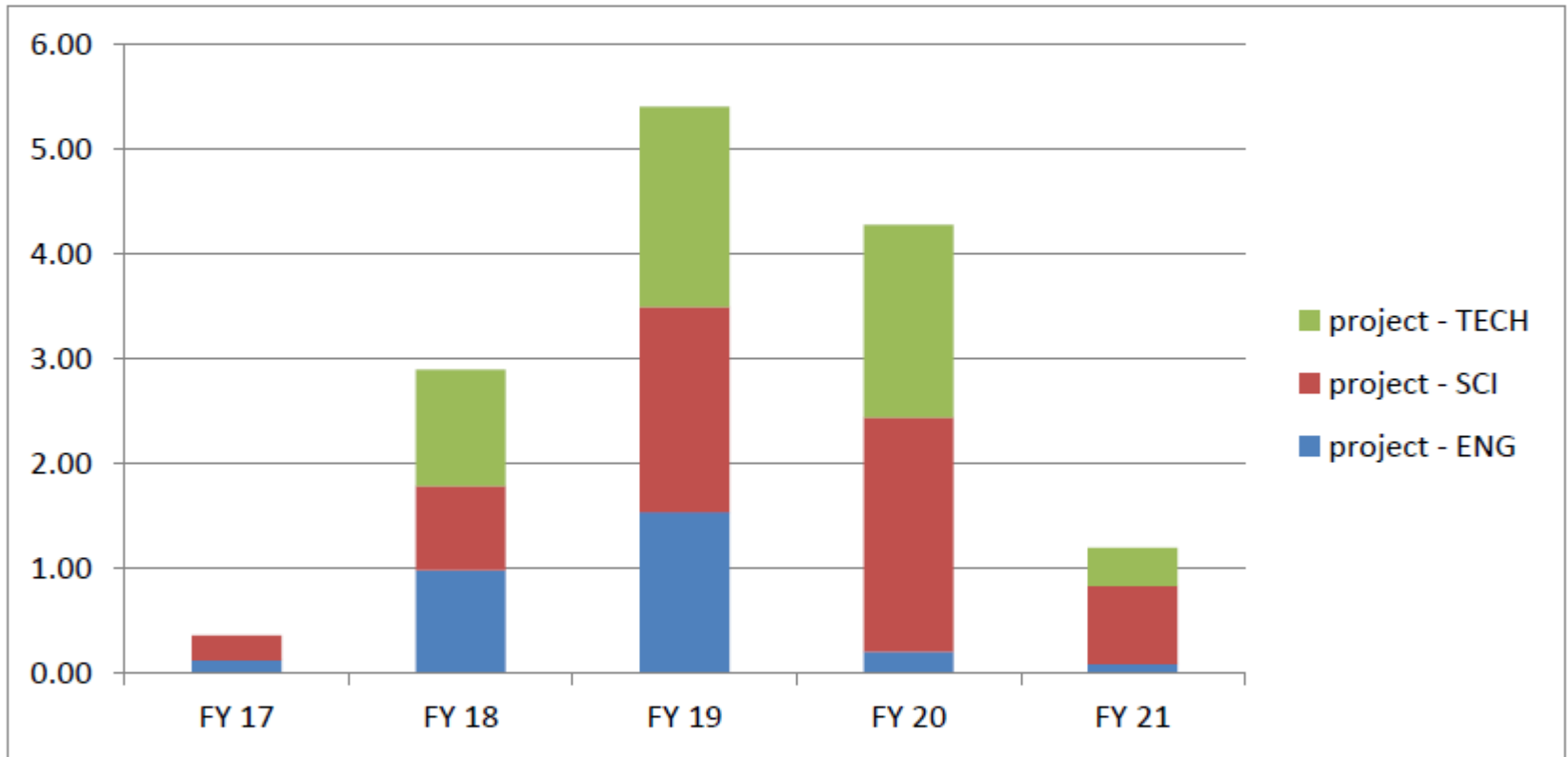
Focus on early readout R&D  
& initial system integration

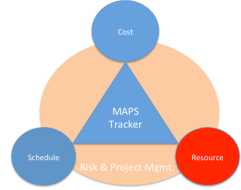


# MAPS Labor Profile



**MAPS Labor profile from resource – loaded schedule sorted by FY and job category**



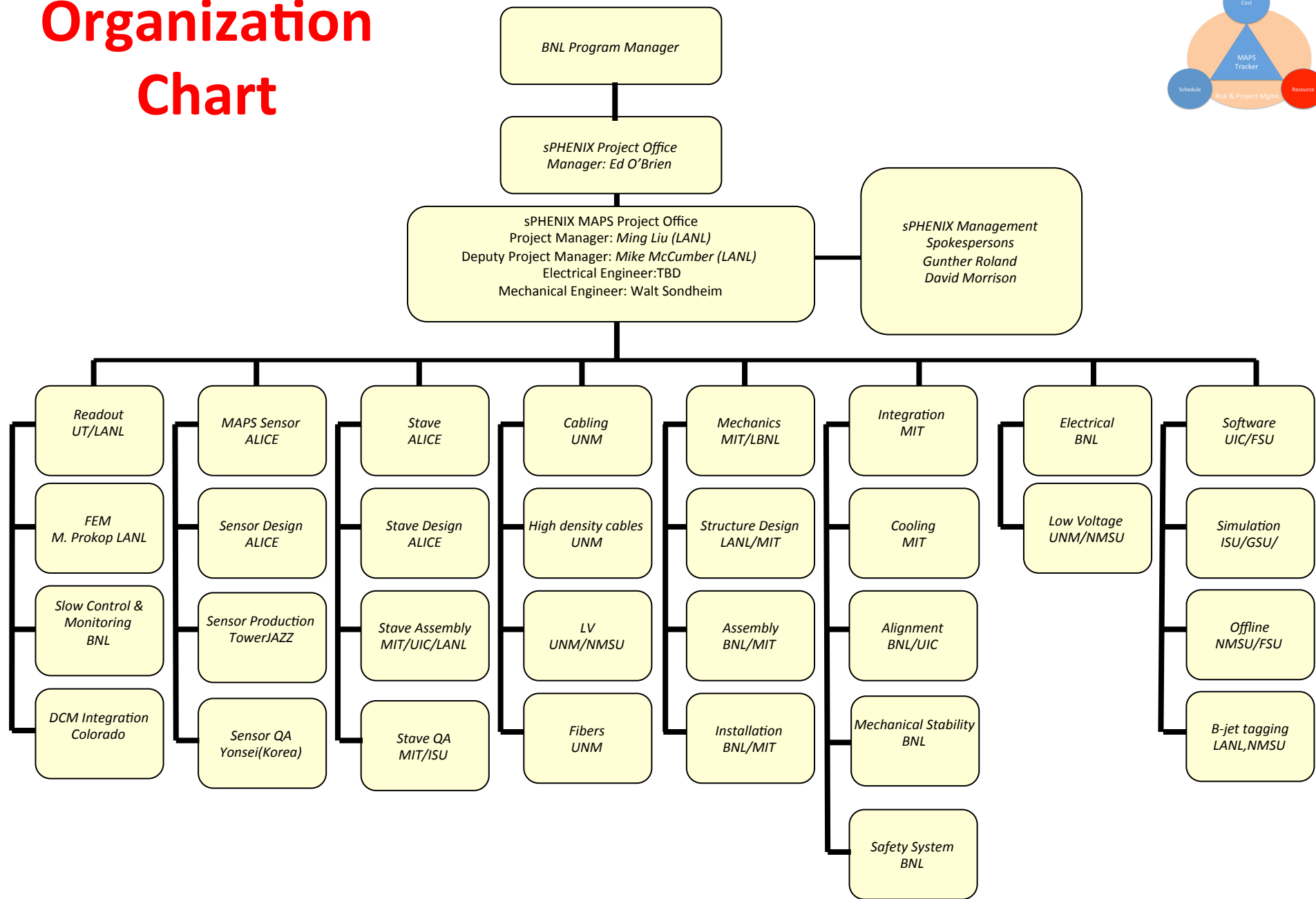
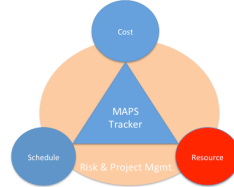


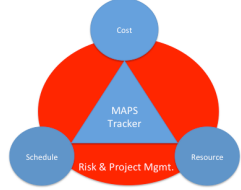
# Participating and Interested Institutions

- LANL - Readout & FEMs, Mechanics
- MIT - Assembly and testing, cooling
- LBNL – Mechanical carbon structures, readout
- 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 – Tracking algorithm and simulations
- Univ. of IL of Chicago – Stave assembly and testing, offline analysis
- Iowa State University – Assembly and testing, simulations
- Georgia State University - Slow control and monitoring
- 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 and readout, simulations

Potential collaboration

# Organization Chart

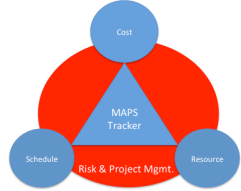




# Risk Mitigation

- Readout electronics R&D to meet CD1 (11/2017)
  - Early procurements of staves and RDO/CRU
  - Joint effort with ALICE/CERN/LBNL
- Mechanical & cooling R&D to meet CD2/CD3 (8/2018)
  - Early R&D support at MIT/BNL
    - sPHENIX mechanical integration
  - Early joint R&D with BNL/LBNL/MIT
- Production and assembly
  - Partial delivery and more parallel efforts

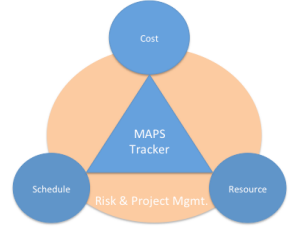
# Plans and Issues



- **MoU with ALICE/CERN: by ~12/2016**
  - Prototype and final stave production and delivery
  - Obtain ALICE readout test stand and electronics for early R&D
  - Obtain design files, electronics and mechanics
  - Training sPHENIX personnel, available manpower
  - R&D collaboration and schedule
  - Availability of CERN facilities after ITS/IB production
- **Schedule/funding gap of stave productions**
  - ITS/IB production: ~1/2017 - Mid/2018
  - sPHENIX CD-3b: 8/2018
  - Risk Mitigation:
    1. Early training through LDRD effort, maintain activity at low level
    2. Possible mortgage for sPHENIX production from ALICE/CERN with MoU
    3. Seek external foreign funding
- **sPHENIX readout R&D**
  - Possible delay due to unavailability of key elements like staves and readout for R&D
  - Risk mitigation:
    - Early joint R&D with ALICE as associate members
    - Start with prototype RDO and CRU



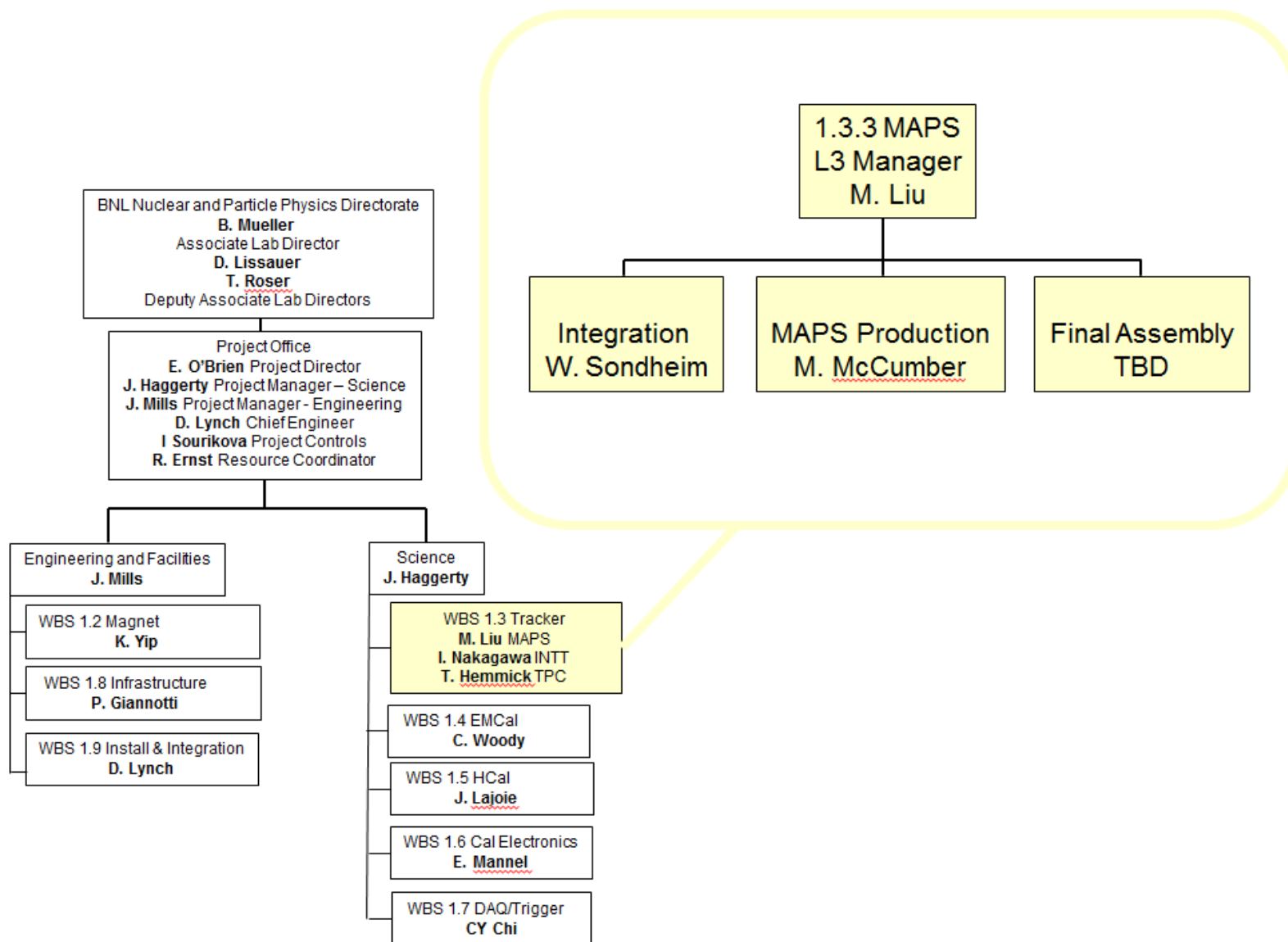
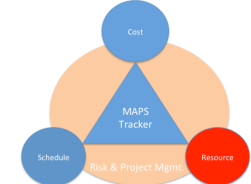
# Summary



- No high risk R&D necessary
- Early MoU with ALICE critical
- LANL LDRD very important
- Early mechanical integration R&D important
- Cost basis is in reasonable shape
- Management plan is in progress
- Installed and ready for beam ~1/2021
- Project has ~6 months float

# Backup Slides

# MAPS Org Chart



# MAPS Labor Profile



MAPS Labor profile from resource – loaded schedule sorted by FY and job category

| Row Labels           | FY 17       | FY 18       | FY 19       | FY 20       | FY 21       |
|----------------------|-------------|-------------|-------------|-------------|-------------|
| <b>project</b>       | <b>0.35</b> | <b>2.90</b> | <b>5.41</b> | <b>4.28</b> | <b>1.19</b> |
| <b>ENG</b>           | <b>0.12</b> | <b>0.98</b> | <b>1.53</b> | <b>0.20</b> | <b>0.08</b> |
| Elec Liason Eng      | 0.06        | 0.06        | 0.06        | 0.06        | 0.04        |
| Electrical Engineer  | 0.00        | 0.04        | 0.05        | 0.00        | 0.00        |
| Electronics Engineer | 0.00        | 0.42        | 1.25        | 0.00        | 0.00        |
| Mech Liason Eng      | 0.06        | 0.06        | 0.06        | 0.06        | 0.04        |
| Mechanical Engineer  | 0.00        | 0.40        | 0.12        | 0.07        | 0.00        |
| <b>SCI</b>           | <b>0.24</b> | <b>0.81</b> | <b>1.96</b> | <b>2.24</b> | <b>0.75</b> |
| Physicist            | 0.24        | 0.81        | 1.96        | 2.24        | 0.75        |
| <b>TECH</b>          | <b>0.00</b> | <b>1.11</b> | <b>1.91</b> | <b>1.84</b> | <b>0.36</b> |
| Elec tech            | 0.00        | 0.12        | 0.44        | 0.82        | 0.18        |
| Mech Tech            | 0.00        | 0.99        | 1.47        | 1.02        | 0.18        |
| <b>Grand Total</b>   | <b>0.35</b> | <b>2.90</b> | <b>5.41</b> | <b>4.28</b> | <b>1.19</b> |

Source of Labor is LANL + MIT with numerous additional institutions expressing interest in participating. Anticipate additional firm institutional commitments over the next few months.

# Cost at LANL M&S and Labor Rates

## sPHENIX MAPS Tracking LANL Labor and Overheads Summary Estimate

|                                             | 2016     | 2017           | 2018             | 2019           | 2020             | 2021           | 2022     | Grand Total      |
|---------------------------------------------|----------|----------------|------------------|----------------|------------------|----------------|----------|------------------|
| <b>sPHENIX Labor</b>                        |          |                |                  |                |                  |                |          |                  |
| Fixed FY16 Direct Labor w/fringe            |          | 126,568        | 381,040          | 109,392        | 332,192          | 46,560         |          | \$995,752        |
| Estimated Composite Indirect on Labor@36.9% | 0        | 158,210        | 476,300          | 136,740        | 415,240          | 58,200         | 0        | 1,244,690        |
| Fixed FY16 Fully Loaded Labor               | 0        | 284,778        | 857,340          | 246,132        | 747,432          | 104,760        | 0        | 2,240,442        |
| Escalation @ 3.0%                           | 0        | 8,543          | 52,212           | 22,816         | 93,803           | 16,685         | 0        | 194,060          |
| Subtotal AY \$                              | 0        | 293,321        | 909,552          | 268,948        | 841,235          | 121,445        | 0        | 2,434,502        |
| Contingency at 40%                          | 0        | 117,329        | 363,821          | 107,579        | 336,494          | 48,578         | 0        | 973,801          |
| <b>Budgeted Labor</b>                       | <b>0</b> | <b>410,650</b> | <b>1,273,373</b> | <b>376,528</b> | <b>1,177,729</b> | <b>170,023</b> | <b>0</b> | <b>3,408,302</b> |

|                                              |            |                  |                    |                    |                    |                  |            |                    |
|----------------------------------------------|------------|------------------|--------------------|--------------------|--------------------|------------------|------------|--------------------|
| <b>Adjusted sPHENIX M&amp;S - MAPS</b>       |            |                  | \$140,000          | \$2,157,710        |                    |                  |            | \$2,297,710        |
| Estimated Composite Indirect                 | 0          | 0                | 35,000             | 539,428            | 0                  | 0                | 0          | 574,428            |
| Subtotal FY 16 \$                            | \$0        | \$0              | \$175,000          | \$2,697,138        | \$0                | \$0              |            | \$2,872,138        |
| Escalation @ 2% per FY                       | 0          | 0                | 7,070              | 165,086            | 0                  | 0                |            | 172,156            |
| Estimate with Escalation                     | \$0        | \$0              | \$182,070          | \$2,862,224        | \$0                | \$0              |            | \$3,044,294        |
| Contingency at 40%                           | 0          | 0                | 72,828             | 1,144,890          | 0                  | 0                | 0          | 1,217,718          |
| <b>Budgeted Material</b>                     | <b>\$0</b> | <b>\$0</b>       | <b>\$254,898</b>   | <b>\$4,007,113</b> | <b>\$0</b>         | <b>\$0</b>       | <b>\$0</b> | <b>\$4,262,011</b> |
| <b>Total AY \$ with Contingency Estimate</b> | <b>\$0</b> | <b>\$410,650</b> | <b>\$1,528,271</b> | <b>\$4,383,641</b> | <b>\$1,177,729</b> | <b>\$170,023</b> | <b>\$0</b> | <b>\$7,670,314</b> |

Overall contingency %

40.0%TPC  
40.0%TEC

# Cost at BNL M&S and Labor Rates

## sPHENIX MAPS Tracking BNL Labor and Overheads

### Summary Estimate

|                                              | 2016       | 2017             | 2018             | 2019               | 2020             | 2021            | 2022       | Grand Total        |
|----------------------------------------------|------------|------------------|------------------|--------------------|------------------|-----------------|------------|--------------------|
| <b>sPHENIX Labor</b>                         |            |                  |                  |                    |                  |                 |            |                    |
| Fixed FY16 Direct Labor w/fringe             |            | 101,254          | 304,832          | 87,514             | 265,754          | 37,248          |            | \$796,602          |
| Estimated Composite Indirect on Labor@36.9%  | 0          | 37,363           | 112,483          | 32,293             | 98,063           | 13,745          | 0          | 293,946            |
| Fixed FY16 Fully Loaded Labor                | 0          | 138,617          | 417,315          | 119,806            | 363,817          | 50,993          | 0          | 1,090,548          |
| Escalation @ 3.0%                            | 0          | 4,159            | 25,414           | 11,106             | 45,659           | 8,122           | 0          | 94,460             |
| Subtotal AY \$                               | 0          | 142,776          | 442,729          | 130,912            | 409,476          | 59,114          | 0          | 1,185,007          |
| Contingency at 40%                           | 0          | 57,110           | 177,092          | 52,365             | 163,790          | 23,646          | 0          | 474,003            |
| <b>Budgeted Labor</b>                        | <b>0</b>   | <b>199,886</b>   | <b>619,821</b>   | <b>183,277</b>     | <b>573,266</b>   | <b>82,760</b>   | <b>0</b>   | <b>1,659,010</b>   |
| <b>Adjusted sPHENIX M&amp;S - MAPS</b>       |            |                  |                  |                    |                  |                 |            |                    |
|                                              |            |                  | \$140,000        | \$2,157,710        |                  |                 |            | \$2,297,710        |
| Estimated Composite Indirect                 | 0          | 0                | 13,202           | 203,472            | 0                | 0               | 0          | 216,674            |
| Subtotal FY 16 \$                            | \$0        | \$0              | \$153,202        | \$2,361,182        | \$0              | \$0             |            | \$2,514,384        |
| Escalation @ 2% per FY                       | 0          | 0                | 6,189            | 144,523            | 0                | 0               |            | 150,713            |
| Estimate with Escalation                     | \$0        | \$0              | \$159,391        | \$2,505,705        | \$0              | \$0             |            | \$2,665,097        |
| Contingency at 40%                           | 0          | 0                | 63,757           | 1,002,282          | 0                | 0               | 0          | 1,066,039          |
| <b>Budgeted Material</b>                     | <b>\$0</b> | <b>\$0</b>       | <b>\$223,148</b> | <b>\$3,507,987</b> | <b>\$0</b>       | <b>\$0</b>      | <b>\$0</b> | <b>\$3,731,135</b> |
| <b>Total AY \$ with Contingency Estimate</b> | <b>\$0</b> | <b>\$199,886</b> | <b>\$842,969</b> | <b>\$3,691,264</b> | <b>\$573,266</b> | <b>\$82,760</b> | <b>\$0</b> | <b>\$5,390,145</b> |

Overall contingency %

40.0%TPC

40.0%TEC

# Collaboration & Management

- Workshops organized in Santa Fe, 4/2016
  - Strong support from ITS/ALICE and other groups
    - LBNL, BNL STAR/HFT group
    - MIT, Yonsei / Korean Institutions
  - Produced 1<sup>st</sup> draft of Cost and Schedule project file
  - Established collaboration with ALICE ITS groups
- MAPS Detector Group Kickoff Meeting 8/19/2016
  - Institutions and their interest
  - Resources and plan
- US institutions
  - MIT HI and ME groups
    - Stave assembly and test at CERN & BNL, cooling, integration etc.
  - LBNL
    - mechanical carbon frame etc
  - BNL
    - Services, DAQ, safety, tech support etc
  - UNM and NMSU
    - Cabling, assembly, simulations and physics analysis
  - U Colorado
    - DAQ and DCM-II integration, simulations and analysis
  - ISU
    - Simulations and analysis, assembly and test
  - GSU
    - Simulations, small controls
  - FSU
    - Offline
  - U California, Riverside/LA/Davis etc
    - Local mechanical and electronics shops, simulations, assembly and test
  - UT Austin
    - Readout electronics
  - UIC
    - Assembly and test, offline
- Other international collaborators
  - RIKEN/RBRC – assembly, test and simulations
  - CCNU/ALICE/ITS
  - Yonsei/ALICE/ITS

## Working on MOU with ITS/ALICE

- Initial discussion with ITS Management
- Associate Membership on ITS/ALICE project
- Obtain 4 staves & readout for R&D ASAP
- Stave production extension, schedule and “mortgage”
- Obtain readout design files
- Mechanical design files
- sPHENIX manpower at CERN
- 2 presentations planned
  - ALICE Management Board meeting
  - 11/11/2016: ALICE Collaboration Board meeting

Expect MOU agreement: 12/2016

# LANL/sPHENIX – ALICE Collaboration

**From:** Luciano Musa <[luciano.musa@cern.ch](mailto:luciano.musa@cern.ch)>

**Date:** Saturday, August 6, 2016 at 9:25 PM

**To:** "Ming Liu (LANL)" <[ming@bnl.gov](mailto:ming@bnl.gov)>

**Subject:** Re: ALICE ITS MAPS project and sPHENIX - ALICE Associate Membership?

Dear Ming,

sorry for the late reply to your previous e-mail. We had two Engineering Design Reviews (mechanics and cooling) and then I was in Jakarta for one week for an ITS Asian Meeting.

I am glad to learn that you succeed obtaining a \$5M grant (congratulations!!) and your plans to become an ALICE associate member to work in the ITS project. This will require a detailed discussion between the two of us for the preparation of an MoU.

I am leaving today for two weeks of vacation and will be back to CERN on August 22nd. I would propose we get in touch on the 22nd or 23rd August, if this is fine for you.

A possible timeline is presentation of your request at the MB of 1st September and at the CB of 11th November.

Kind Regards,  
Luciano

**Plan: ITS/ALICE associate members by the end of 2016**



# Forming the Collaboration

- **On board:**  
LANL, MIT, UNM, RIKEN, NMSU, BNL, Colorado, ISU, GSU, UT-Austin, UCLA
- **Potential:**  
LBNL, UIC, UCR, UC Davis, Korean Institutes
- **Consulting:**  
ALICE/CERN, Yonsei/Korea, CCNU/China

# Resources I

- 1. LANL:
- Supported by LDRD (FY17-19), will develop a 4-stave MAPS prototype to fully test the readout chain from MAPS to sPHENIX DAQ, and also initial mechanical design.
- Provide electronics and mechanical engineering support through LDRD at least.
- 2. MIT:
- Both HI and ME groups are joining the MAPS efforts, strong physics and engineering capabilities (Bates Center); extensive experience on technical integration and cooling system, worked on STAR HFT in collaboration with LBNL.
- already have many students and postdocs working at CERN, could help on MAPS stave assembly and testing at CERN;
- Could lead the stave assembly and testing at CERN and BNL, cooling and mechanical integration effort
- 3. LBNL:
- Extensive experience in mechanical carbon structure and MAPS readout electronics, worked on PHENIX/FVTX carbon frame supporting structure, already have test stand developed for the on-going ALICE MAPS upgrade project, will make a decision soon on joining the sPHENIX project.
- Could lead the mechanical carbon support structure, assembly and testing of staves etc
- 4. BNL:
- Strong technical capabilities in mechanical structure and DAQ, computing, slow control, safety and tech support, could lead the MAPS “Services” tasks;

## Resources II

- 5. Univ. of Colorado
- Extensive experience with DAQ electronics, DCM-II and slow controls, close to LANL for collaborative work, excellent physics and simulation capabilities
- Could lead the DAQ DCM-II integration effort and simulation work
- 6. ISU
- Plan to add one postdoc to work on various MAPS related tasks and simulations, have several students
- Could take a major role on simulation effort, and testing MAPS
- 7. FSU
- Could continue to lead the tracking software effort, one graduate student
- 8. UNM
- Extensive experience through PHENIX Muon Tracker and FVTX projects on cabling, LV distribution and high density cables etc.
- Could lead effort on LV and cabling, design, testing and integration

## Resources III

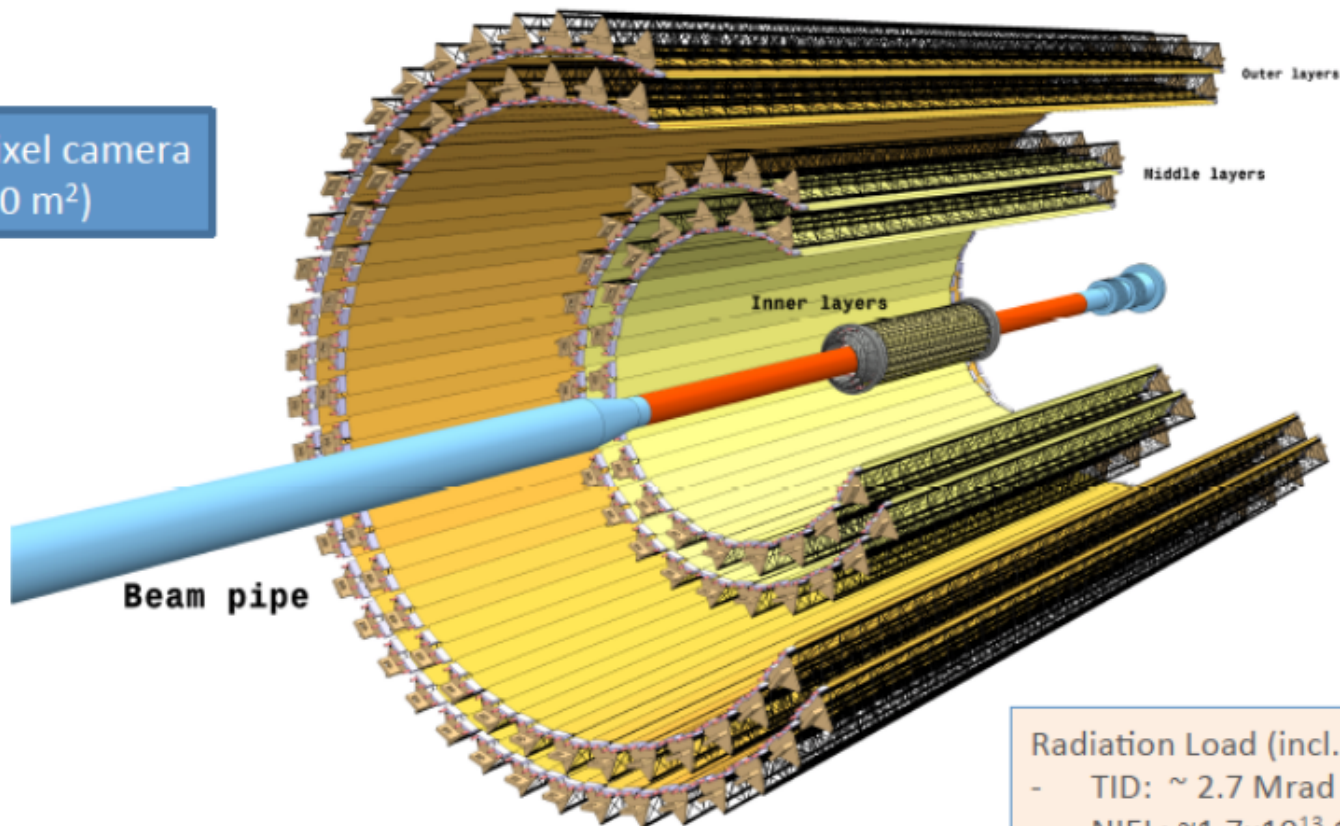
- 9. NMSU
  - Extensive experience with software and simulations, LV/HV control system etc.
  - Could play a major role on simulations, heavy-flavor tagging and physics analysis, provide manpower for testing and assembly work
- 10. GSU
  - Strong physics interest in heavy flavor, could play a major role on simulations and analysis, capable to develop small electronics control system
- 11. UCLA
  - Interested in MAPS hardware and heavy flavor physics, could play a major role on MAPS prototype R&D work and simulations, will send one student to work on LANL's LDRD project
- 12. UCR/UCDavis
  - Interested in MAPS project, heavy flavor physics, have local "very cost effective" machine and electronics shop to fabricate small structures and devices
- 13. Yonsei/Korea
  - Leading ALICE MAPS QA, could contribute to the production QA of MAPS chips, simulations and analysis
- 14. RIKEN/RBRC
  - Interested in MAPS project, from simulation to stave assembly and testing.

# New ITS Layout

A Large Ion Collider Experiment



12.5 G-pixel camera  
( $\sim 10 \text{ m}^2$ )



Radiation Load (incl. safety factor 10)  
- TID:  $\sim 2.7 \text{ Mrad}$   
- NIEL:  $\sim 1.7 \times 10^{13} \text{ 1MeV n}_{\text{eq}} / \text{cm}^2$

## 7-layer barrel geometry based on CMOS Sensors

$r$  coverage: 23 – 400 mm

$\eta$  coverage:  $|\eta| \leq 1.22$

for tracks from 90% most luminous region

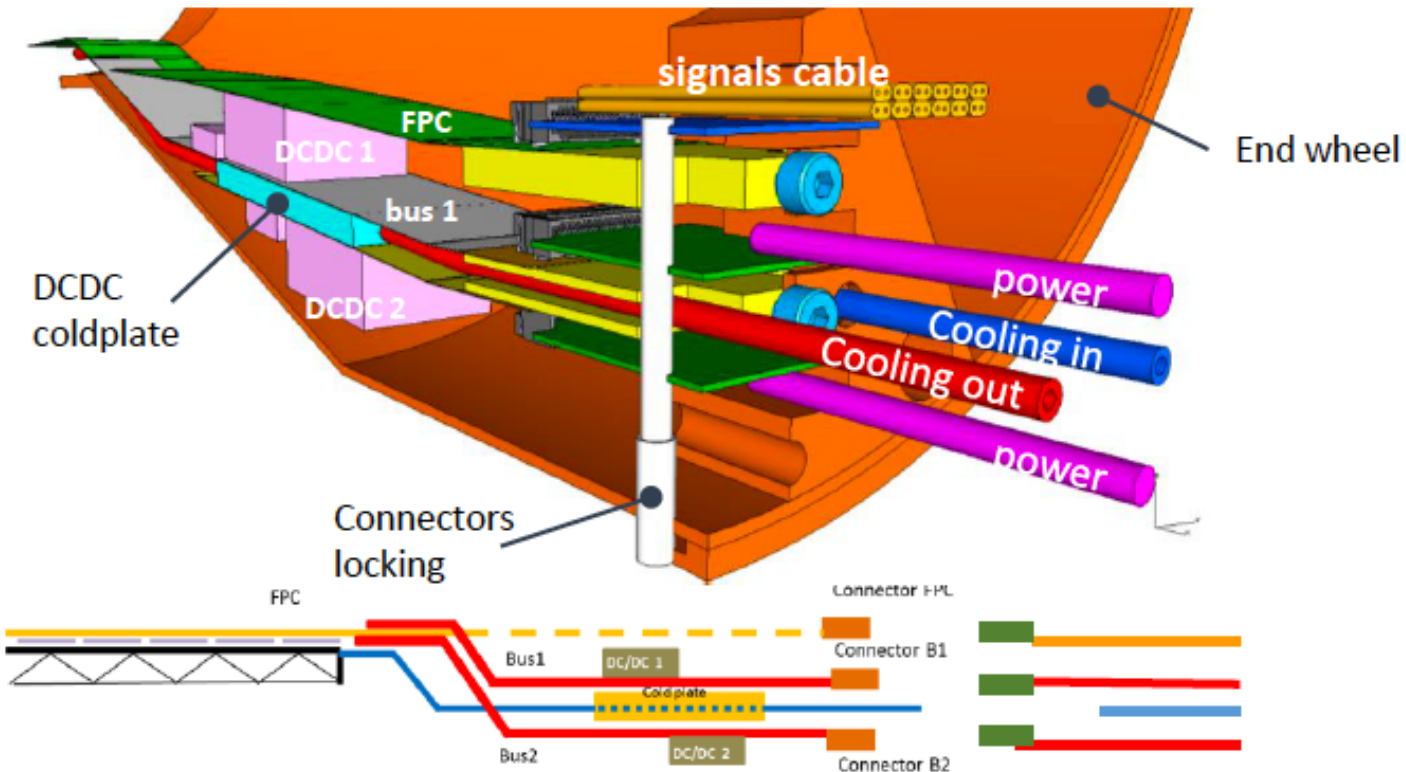
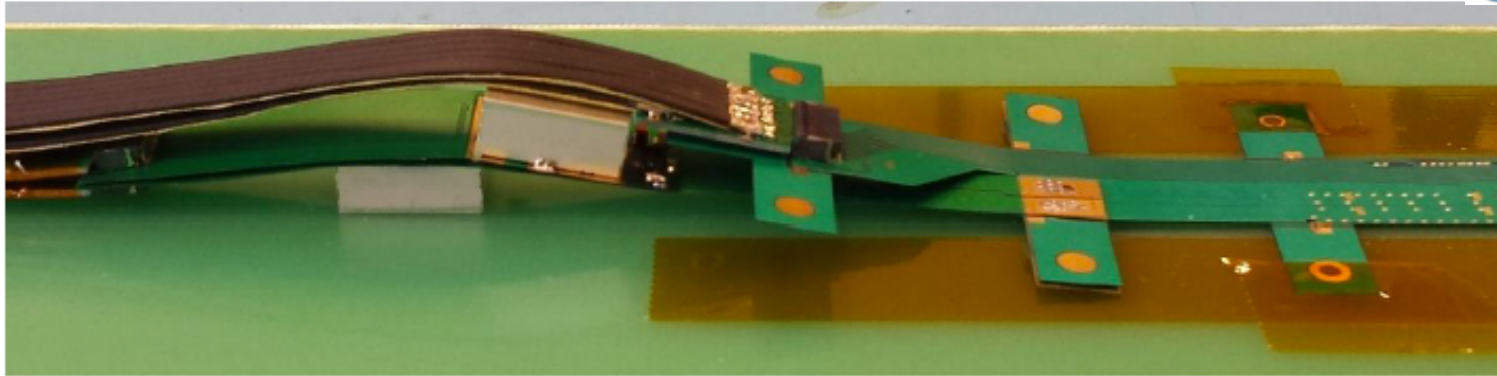
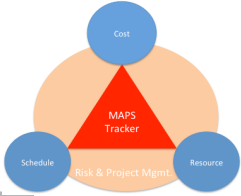
3 Inner Barrel layers (IB)

4 Outer Barrel layers (OB)

Material /layer : 0.3%  $X_0$  (IB), 1%  $X_0$  (OB)

sPHENIX

# MAPS Service Lines



# 3-Layer vs 2-Layer

- Cost reduction

- Stave and electronics cost and schedule
  - Saving \$661K
- Labor: testing/assembly, installation and commissioning
  - Saving  $\sim 28/68 \times (206+186+47) = \$180\text{K}$

Total saving  $\sim \$661 + \$180 = \$842\text{K}$

- 3 Layers: total \$1,681K

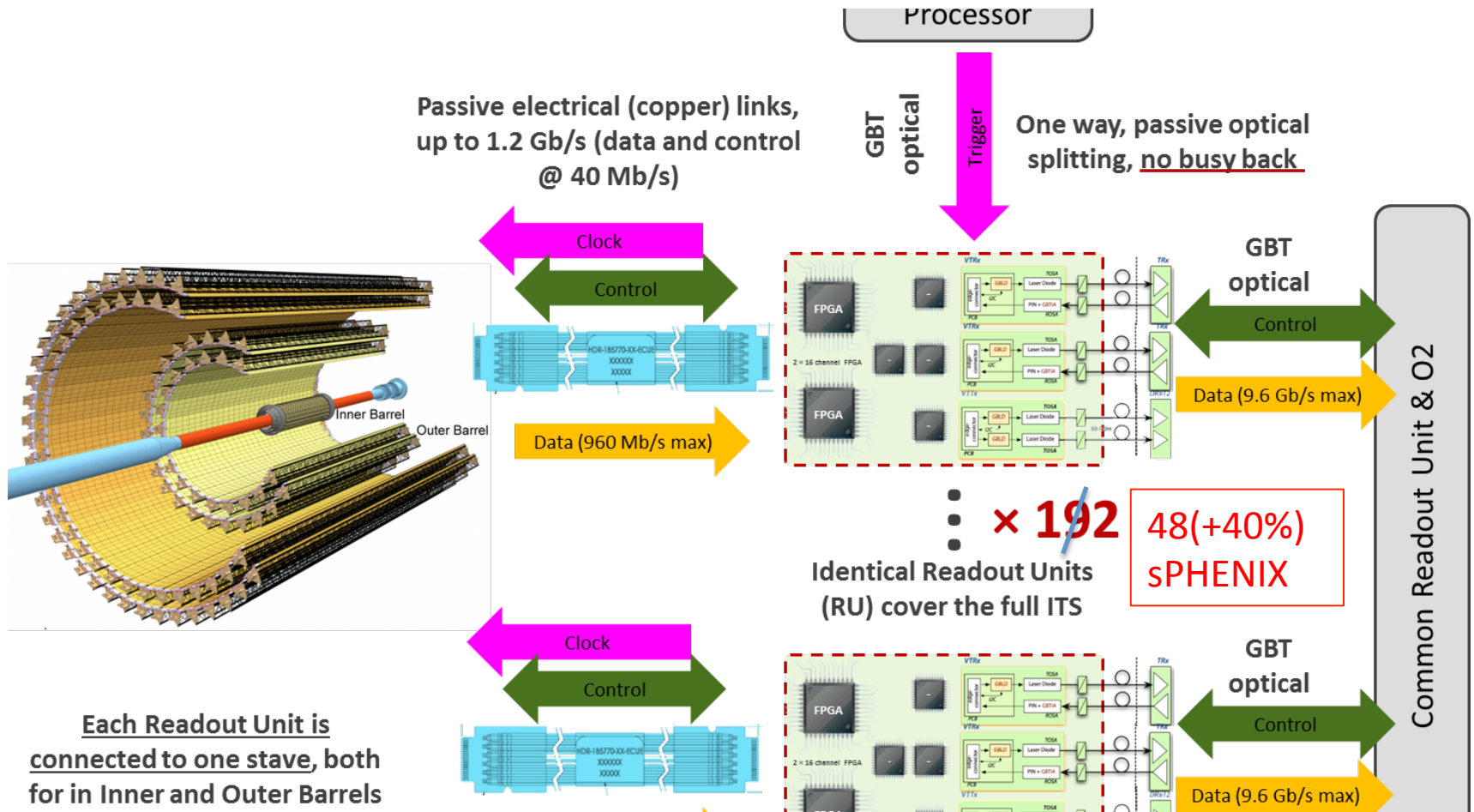
- $(12+16+20)+20 = 68$  staves
  - Cost:  $\$945 + \$164 = \$1,109\text{K}$
  - Schedule: 180 days
- 68 RDOs:
  - Cost:  $\$266 + \$32 = \$298\text{K}$
- 34 CRUs:
  - Cost:  $\$272 + \$2 = \$274\text{K}$

- 2 Inner Layers: total = \$1020K

- $(12+16)+12$  ALICE layers 0 & 1 = 40 staves
  - Cost:  $40/68 \times \$1,109\text{K} = \$652\text{K}$
  - Schedule: 106 days
- 40 RDOs
  - $40/68 \times \$298\text{K} = \$175\text{K}$
- 24CRU:
  - $24/34 \times \$274\text{K} = \$193\text{K}$

# Cost Basis For Electronics

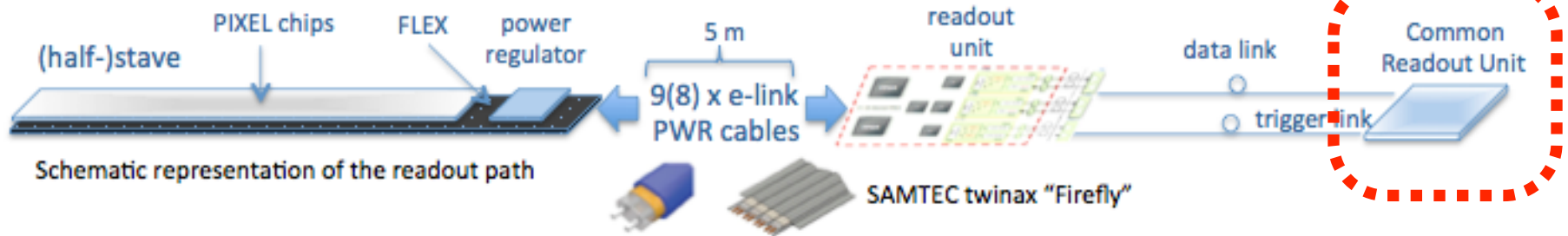
J. Phys. G: Nucl. Part. Phys. **41** (2014) 087002



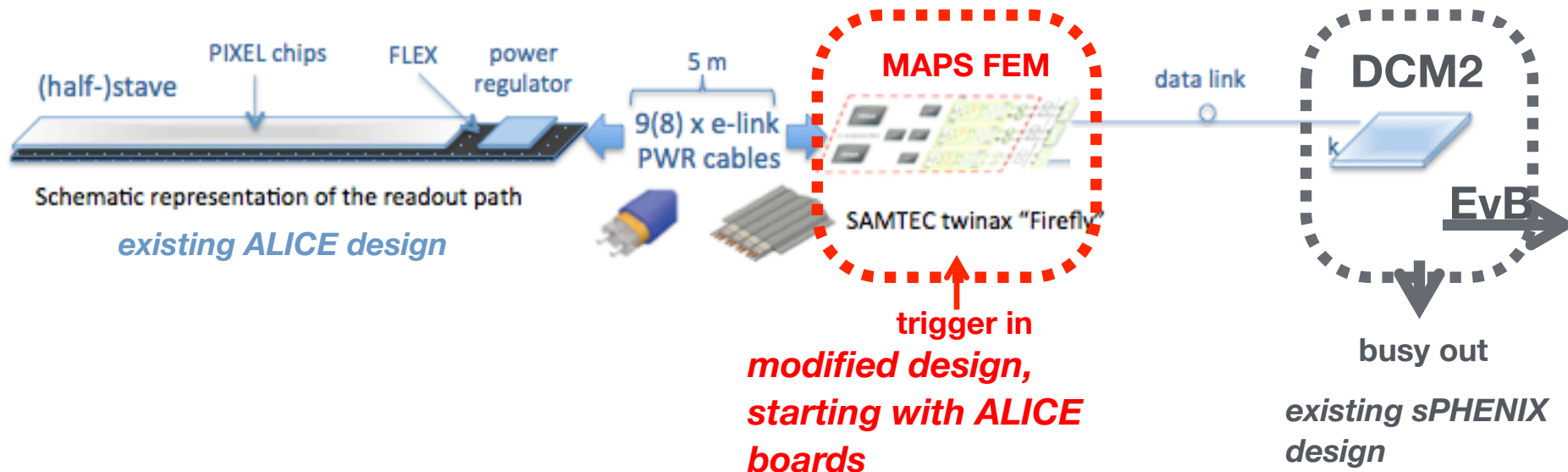


# MAPS Electronics

## ALICE readout path



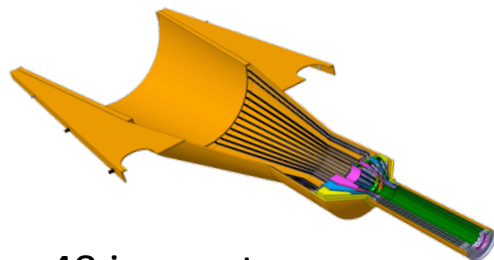
## Plan B: sPHENIX readout path (held as contingency)



# 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 RDO boards

sPHENIX: 48 +40% = 68

ITS IB:

Produce 120 staves in one year

120% contingency

# Key Electronics Readout R&D

- Mostly carried out by LANL LDRD
  - Complete readout electronics design and test by CD-1 (8/1/1017)
- Modify ALICE ITS readout data format to meet sPHENIX DAQ requirements
  - Plan-A:
    - Reprogram CRU to send data directly to PCI/sPHENIX Evt-Builder
  - Plan-B:
    - Build a custom board to convert ALICE data format into sPHENIX DAQ/DCM-II format

Assigned large contingency in both cost and schedule for the readout R&D

# Electronics R&D @LANL

- Obtained MAPS v3 at LANL
- R&D lab setup through LANL fund
  - To setup sPHENIX DAQ/DCM-II
  - MAPS readout integration
  - Reuse FVTX FEMS?

**1st MAPS prototype sensor being studied at LANL**

LBNL R&D expert visited LANL May 2-4<sup>th</sup>

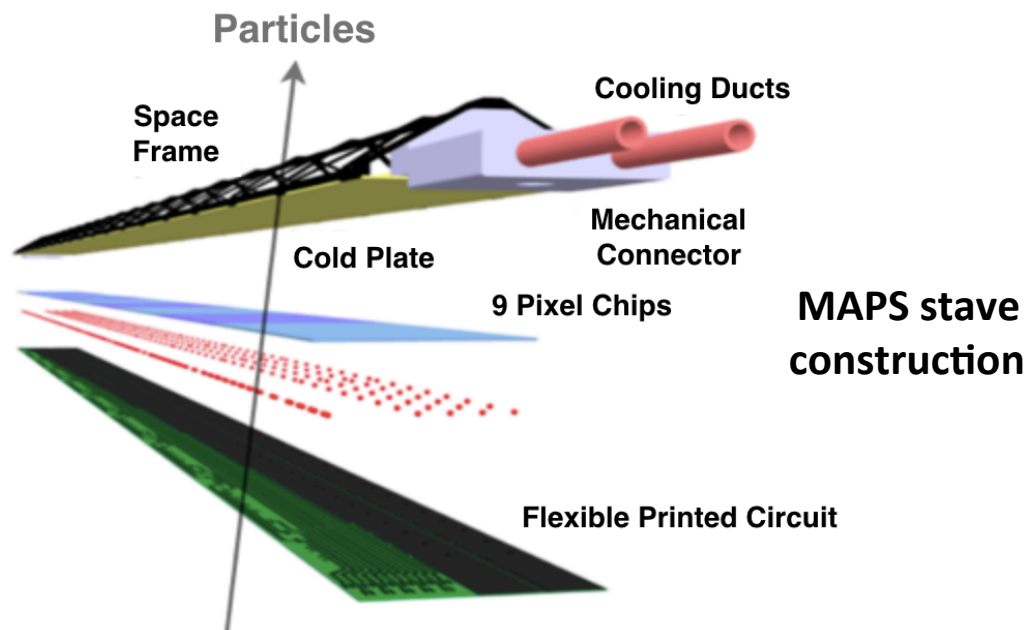
Mike's expertise on DCM-II



# LANL R&D Deliverable: a Prototype Tracker

LDRD Experimental Goal: LANL-built 4-stave prototype tracker at test beam  
with custom sPHENIX readout

**1st MAPS prototype sensor  
being studied at LANL**



**Annual Fermilab  
Test beam**

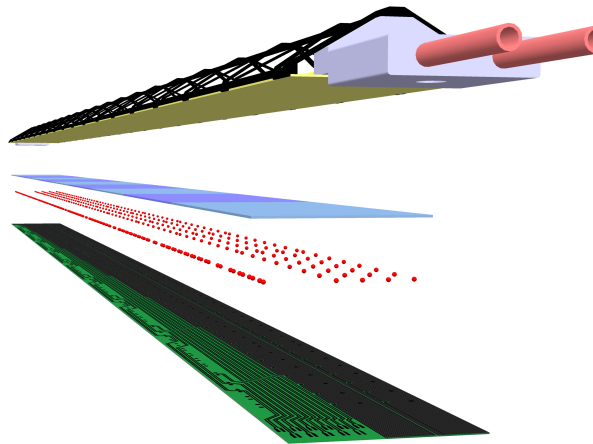
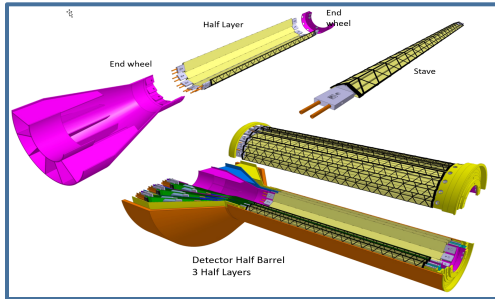
Test prototype tracker  
Validate tracking and  
reconstruction



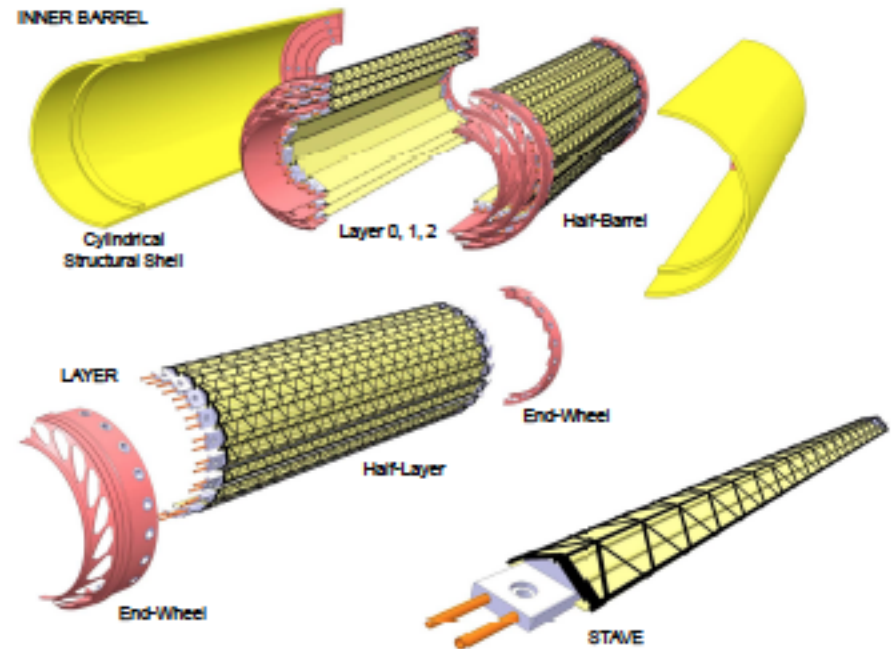
Custom front end, integrate into  
sPHENIX readout (FVTX expertise)



# ALICE Stave and Global Support Structure Cost and Schedule Basis



ALICE Stave



(a) ITS Inner Barrel design.

J. Phys. G: Nucl. Part. Phys. **41** (2014) 087002

# Cost breakdown

Musa @Santa Fe  
Workshop, 4/1/16

A Large Ion Collider Experiment



ALICE

| Activity                               | Material Costs | Manpower Costs | TOTAL COST / ITEM |
|----------------------------------------|----------------|----------------|-------------------|
| <u>1. Pixel Chip</u>                   | 4847           | 170            | 5017              |
| 1.1 CMOS Wafers                        | 3611           |                | 3611              |
| 1.2 Thinning & Dicing                  | 800            |                | 800               |
| 1.3 Series test                        | 436            | 170            | 606               |
| <u>2 Inner Barrel</u>                  | 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                |
| <u>3 Outer Barrel HIC</u>              | 1447           | 1118           | 2565              |
| 3.1 FPC (construction and test)        | 247            | 88             | 335               |
| 3.2 HIC (assembly and test)            | 1200           | 1030           | 2230              |
| <u>4 Middle Layers Staves</u>          | 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               |
| <u>5 Outer Layers Staves</u>           | 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 recovery  
for CERN labor  
-\$500K  
(cover in production  
labor cost)  
"Buy staves"  
and MoU

Total ~\$1M

# Cost breakdown

A Large Ion Collider Experiment



| Activity                                       | Material Costs | Manpower Costs | TOTAL COST / ITEM |
|------------------------------------------------|----------------|----------------|-------------------|
| <a href="#">6 Inner Barrel Global Assembly</a> | 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                |
| <a href="#">7 Outer Barrel Global Assembly</a> | 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 Conyical 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                |
| <a href="#">8 Integration in ALICE</a>         | 91             | 262            | 354               |
| 8.1 Cage                                       | 61             | 153            | 215               |
| 8.2 Installation Tooling                       | 30             | 109            | 139               |



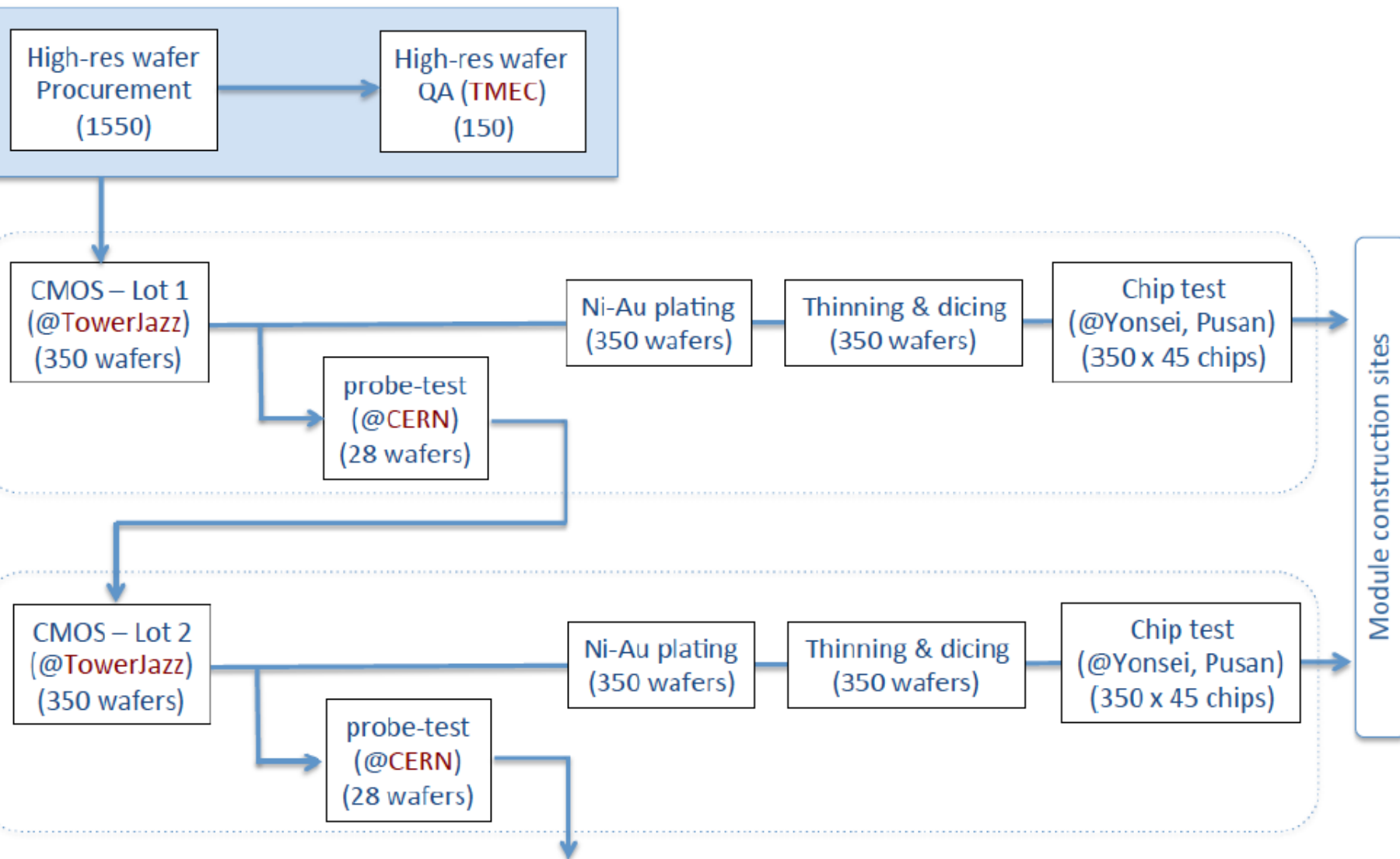
# Cost breakdown

A Large Ion Collider Experiment



| Activity                              | Material Costs | Manpower Costs | TOTAL COST / ITEM |
|---------------------------------------|----------------|----------------|-------------------|
| <a href="#">9 Readout Electronics</a> | 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               |
| <a href="#">10 Power distribution</a> | 1149           | 50             | 1199              |
| 10.1 Power Supplies                   | 750            |                | 750               |
| 10.2 Power Distribution               | 242            | 50             | 292               |
| 10.3 Power Regulation                 | 157            |                | 157               |
| <a href="#">11. DCS</a>               | 150            |                | 150               |
| <a href="#">12. Cooling</a>           | 620            | 0              | 620               |
| 12.1 Water Cooling Plant              | 470            |                | 470               |
| 12.2 Ventilation Humidity Plant       | 150            |                | 150               |
| <b>GRAND TOTAL</b>                    | <b>9947</b>    | <b>3693</b>    | <b>13640</b>      |

# Pixel chip production flow chart



# Module and Stave production flow chart

