# Inner Barrel MAPS Tracker

MAPS Cost and Schedule Mini-Review

June 30th 2016

# Plan for Today

**We have prepared 3 talks for today:**

**Ming:** Overview of MAPS Project Status (20')

**Mike:** Detailed Review of Project File (>60')

**Cesar:** Description of Organization Chart (30')

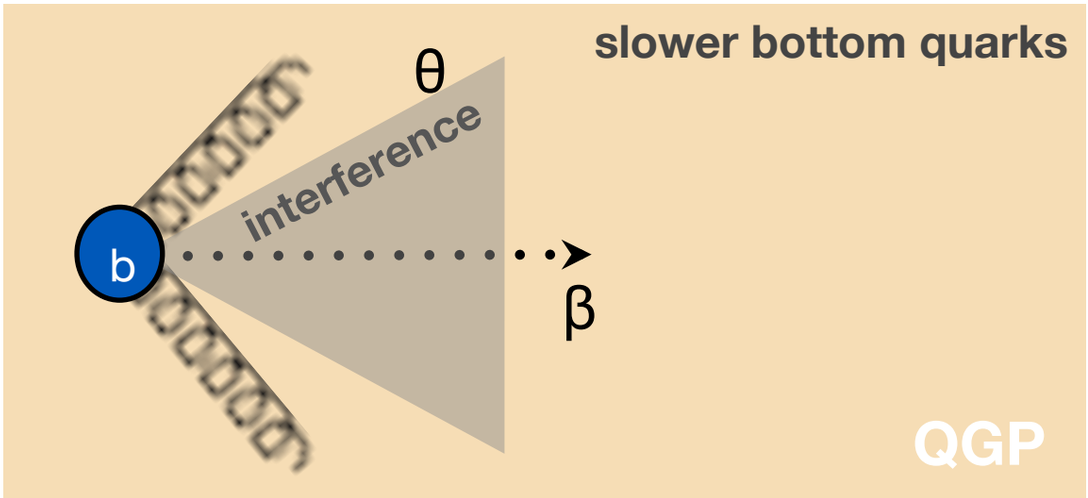
**We expect the homework generated today will be very helpful in our preparations for the September review**

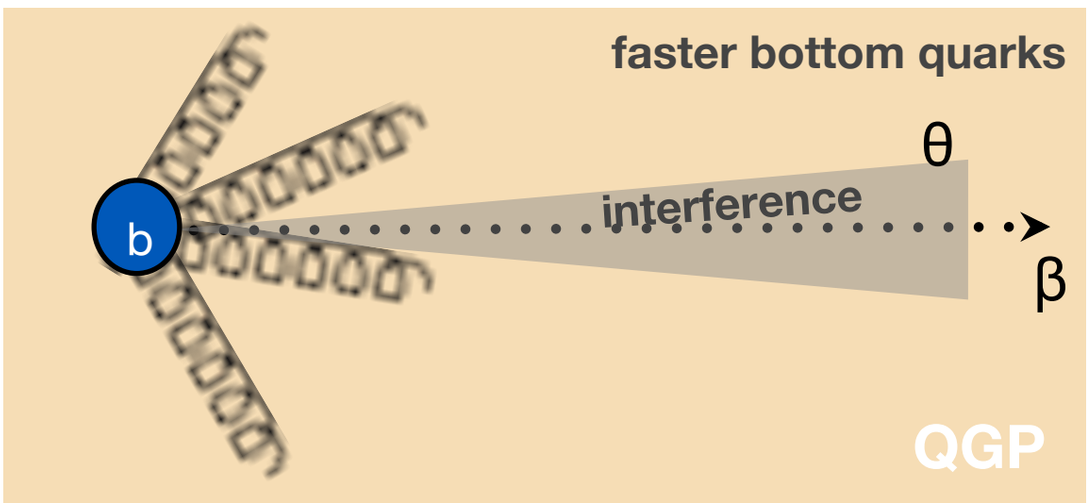
# Overview of MAPS Project

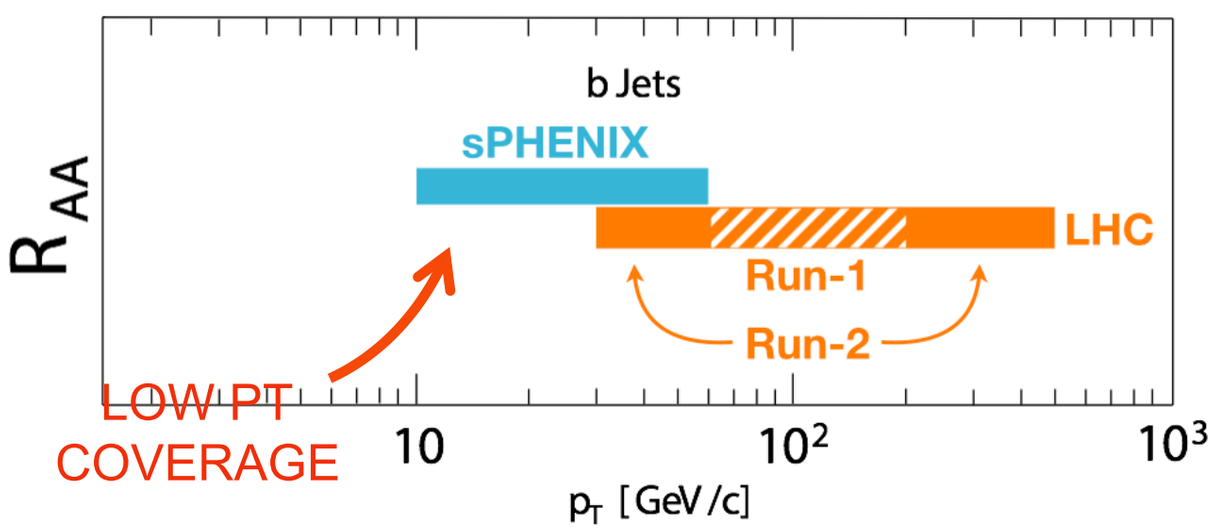
- How we got here
- LANL sPHENIX LDRD proposal
- Current status
- Work for the summer and beyond
  - Sept. 7-9 Tracker Review
  - Nov(?) sPHENIX BNL C&S Review
  - CD1 (Nov. 2017?)

# B-jet Physics: Energy Loss at "Low pT"

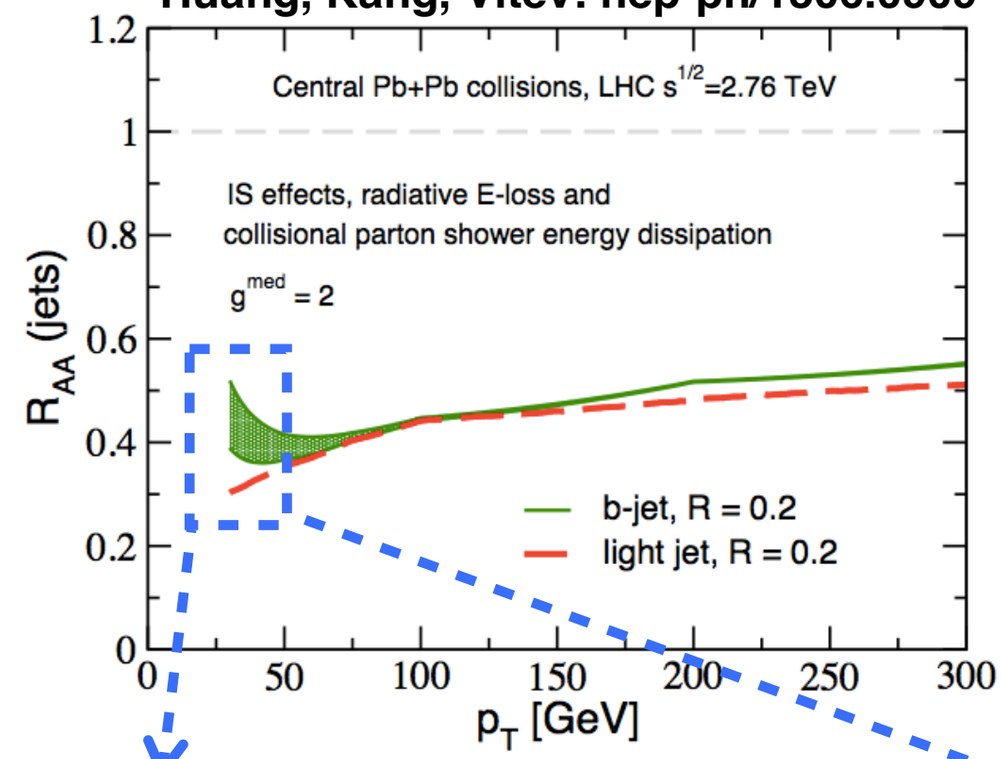
**Major Pillar of the sPHENIX Program (1/3 of the Science Output)**

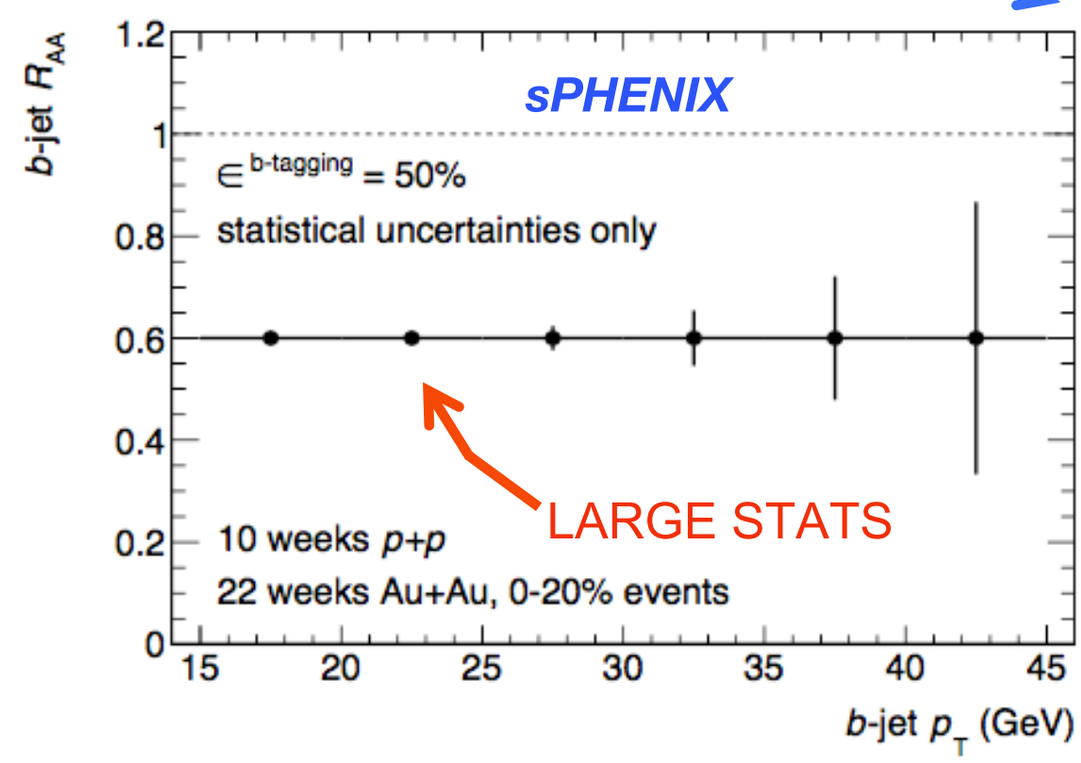


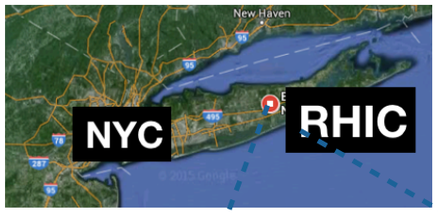




**Huang, Kang, Vitev: hep-ph/1306.0909**

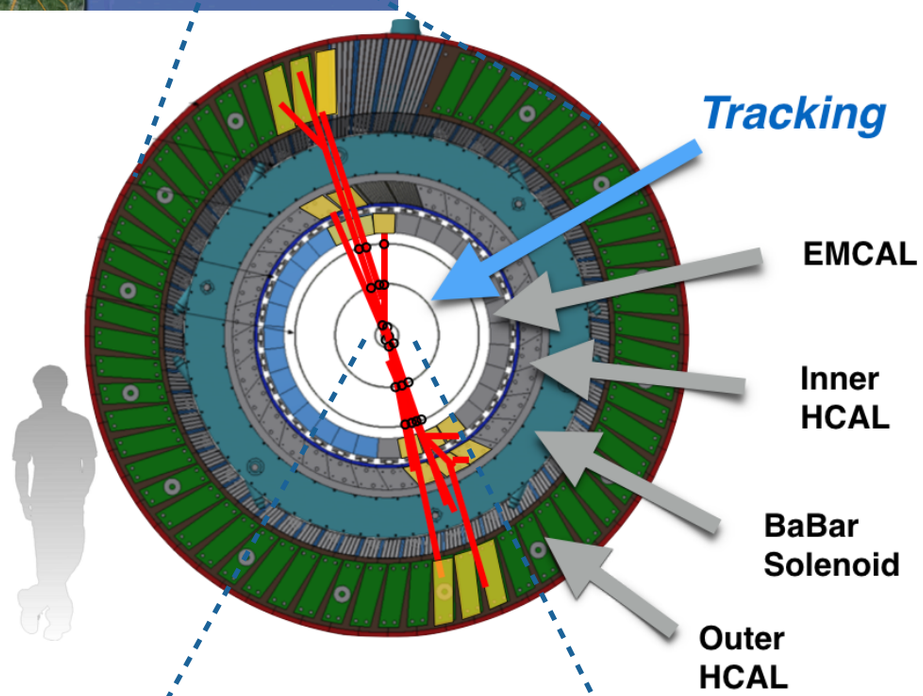


# LANL's Interest in sPHENIX

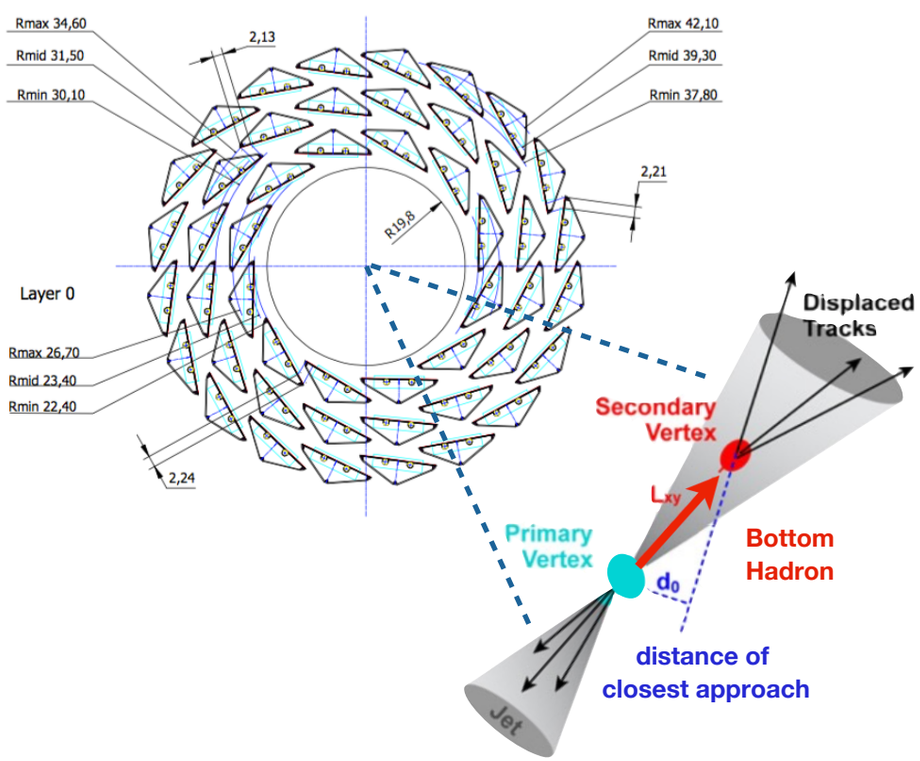



## Jets, Heavy Flavor Jets, and Upsilons at RHIC 2022+




**Physics:** study of QGP structure over a range of length scales and temperatures with **hard-scattered probes inc. bottom quark jets**

LANL's long history and expertise with heavy flavor physics and silicon tracking: **design and construct an inner tracker** for many specialized measurements, especially for **bottom quark jet observables**.




**Inner Silicon Concept with Monolithic Active Pixel Sensors (MAPS):**

- Very fine pitch (28x28 um), high efficiency (>99%)
- Optimizations for material thickness, ~0.3%/layer
- 15+ years of R&D from ALICE

# sPHENIX Tracking Workshops in Santa Fe

1st Pre-DNP sPHENIX Tracking Workshop held in Santa Fe, Oct. 27, 2015
https://indico.bnl.gov/conferenceDisplay.py?confId=1364

Discussed various options for sPHENIX Tracking needs
MAPS technology clearly stands out from others

**LANL MAPS Silicon Option**
was examined at Santa Fe MAPS Cost & Schedule Workshop, Mar 30-Apr. 1, 2016

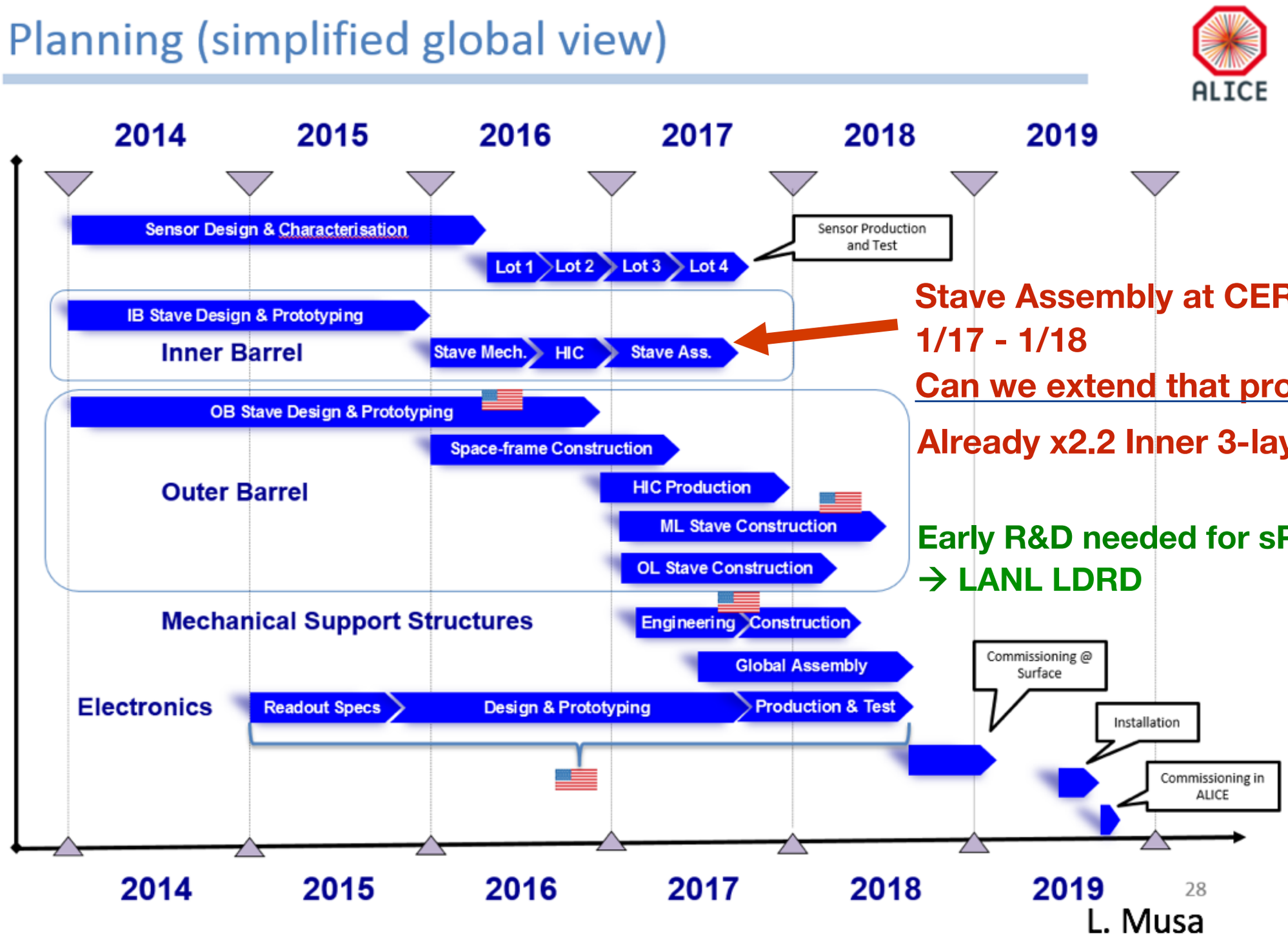
**Excellent turn-out from sPHENIX, ALICE, STAR/HFT, EIC experts**

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

Take Home:
- Extension of ALICE production possible
- Inner tracker cost <$5M inc. contingency

# ALICE Construction Schedule

## Current Schedule *+ add ~6 months*




**Stave Assembly at CERN**
**1/17 - 1/18**
**Can we extend that production?**

**Already x2.2 Inner 3-layers**

**Early R&D needed for sPHENIX**
**→ LANL LDRD**

# LANL LDRD Proposal



## Probing Quark-Gluon Plasma with Bottom Quark Jets at sPHENIX

*PI:* Liu, Ming, X.; P-25; mliu@lanl.gov

### Introduction

A few microseconds after the Big Bang, while still at a temperature of several trillion degrees, the entire universe was permeated with quark-gluon plasma (QGP). Measurements at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL), where LANL plays a major role, and the Large Hadron Collider (LHC) at CERN have verified the existence of the QGP [1-4]. However, none of the existing experiments have revealed its microscopic structure, thus motivating a new experiment named sPHENIX [5]. We propose to use a combination of experimental, theoretical, and engineering expertise from LANL's P, T, AOT, and CCS Divisions to develop the next generation heavy ion physics program at LANL. We will design a new cutting-edge, low mass, high efficiency pixel-based inner tracking detector (Figure 1) needed for the sPHENIX experiment. This proposed $75M experiment will usher in a new era of fundamental discoveries in nuclear science and reveal the internal structure of the QGP near the transition temperature to conventional nuclear matter. The proposed Monolithic Active Pixel Sensor (MAPS [6]) inner tracking detector will provide an order of magnitude improvement in spatial resolution over current technologies and produce the first bottom-quark jet (b-jet) tomographic measurements of the QGP at RHIC. The data will shed new light on our understanding of b-jet interactions with the QGP medium and provide critical new information to pinpoint the transport properties of the QGP. B-jet measurements will fulfill one of the three major science pillars of sPHENIX. We will also develop the state-of-the-art theoretical and computational tools necessary to interpret and optimize the planned experimental measurements. Dr. Geesaman, chair of the DOE Nuclear Science Advisory Committee (NSAC) writes "This LDRD project will be exceptionally valuable for LANL, nuclear science and the nation."

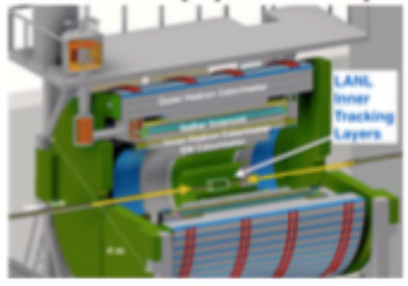



**Figure 1:** The sPHENIX conceptual design. Our proposed inner tracking subsystem is closest to the beam line.

### Project Goals

When the fundamental constituents of matter, quarks and gluons, traverse the QGP they scatter and lose a large amount of energy before escaping, a phenomenon that is extremely useful for probing properties of the QGP [7]. The interactions of those particles with the plasma can be used to directly infer its microscopic quasiparticle structure. The final state observable is a jet, the collimated spray of particles created by fragmentation of the scattered high-energy quark or gluon. Bottom quarks, which are ~1,000 times heavier than the light quarks, produce unique energy loss signatures due to their large mass (4.2 GeV/c$^2$). At momenta comparable to this scale, bottom quarks will preferentially lose energy via collisions with the plasma quasiparticles and not via gluon radiation, as is preferen-

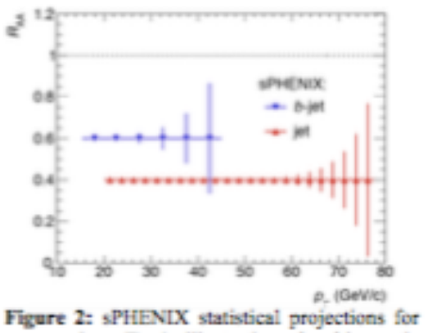



**Figure 2:** sPHENIX statistical projections for suppression ($R_{AA}$) illustrating the kinematic coverage for b-jets (blue triangles) and light jets (red triangles) [5].



Funding Profile:

$5M spread over 3 years starting in Oct 2016

Funding Breakdown:

~1/3 M&S
~1/3 Experiment Staffing
~1/3 Theory Staffing

Proposals judged on many factors, coverage from multiple divisions, strong Theory is necessary to success

**M&S total: $1.5M** **Eng.: $500K**

**Total Project Discount: $2M**

**LDRD submitted on May 12 and defended on June 2nd.**
**Favorably reviewed, on the short list**
**Decision Day: July 7th, 2016**

# Strong Letters of Support

*The sPHENIX Experiment at RHIC*

Dr. Dave Morrison
sPHENIX Co-Spokesperson
Brookhaven National Laboratory
Upton, NY 11973

Prof. Gunther Roland
sPHENIX Co-Spokesperson
Massachusetts Institute of Technology
Cambridge, MA 02139

Dear LANL LDRD Committee Members and other interested persons,

We are pleased to strongly support the proposal for Los Alamos National Laboratory Directed Research funding to develop an inner tracking technology for measuring bottom quark jets at sPHENIX. As the Co-spokespersons of the sPHENIX experiment, a new experiment at the Relativistic Heavy Ion Collider that is currently undergoing technical design development, we give the proposal our strongest endorsement and encourage its timely adoption.

The sPHENIX physics program is designed to investigate the scale dependent dynamics that underlie the properties of the Quark Gluon Plasma. The experiment is specifically mentioned as the top recommendation for our field in the 2015 Long Range Plan for Nuclear Science. The proposed measurement of bottom quark jets is directly aligned with the physics mission outlined in the Long Range Plan. The installation of the sPHENIX detector construction is scheduled to start in 2019, with data taking beginning in 2022. To ensure a successful measurement of bottom quark jets, research and development on the precision inner tracker should begin as soon as possible. We believe the LANL team's proposal is essential to this pillar of the sPHENIX mission.

The team in P-25 has previously constructed important detectors for PHENIX, including the Muon Tracker and Forward Vertex detectors. Dr. Michael McCumber, the Frederick Reines Fellow on the PHENIX team, has an excellent track record of accomplishment and is extremely well-regarded in the collaboration. He is one of the primary authors of twelve PHENIX physics papers, and has represented the PHENIX collaboration numerous times in talks at international conferences. Mike's deep involvement in the sPHENIX proposal led to his invitation to present the case for "Updated jet performance and algorithmic approaches" at the successful DOE review of the sPHENIX science case in April 2015. He has taken a leading role in pursuit of the state-of-the-art tracking solution required by the sPHENIX science aims.

This proposal will have a critical impact on the experimental output of the sPHENIX experiment and is strongly complemented by contributions from LANL theorists. Calculations of b-jet observables, including intra-jet observables, are needed for guiding development of the future RHIC program. The LANL theorists on the proposal

**"We give the proposal our strongest endorsement and encourage its timely adoption"**
**~ our Spokespersons**

Argonne NATIONAL LABORATORY

**Donald F. Geesaman**
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**Physics Division**
Argonne National Laboratory
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Argonne, IL 60439-4845

May 5, 2016

Letter of Support for the LDRD proposal "Probing Quark-Gluon Plasma with Bottom Quark Jets at sPHENIX"

This LDRD proposal addresses an extremely important avenue of research in the physics of the hot, dense state of matter that is the strongly coupled quark-gluon liquid. Heavy quarks shed new light on the physics because, by the nature of the large b quark mass, they immediately bring a hard scale to the dynamics. The scientific impact of these studies have been documented in numerous publications. To date studies of b quark dynamics at RHIC have been limited primarily to bottom-antibottom pairs, the Upsilon particles, as the existing detectors did not have the resolution and coverage to measure displaced vertices sufficiently well. This proposal addresses the major experimental issue of finding a suitable precise and low mass detector technology with an order of magnitude improvement in spatial tracking resolution and also the rapidly advancing theoretical issues of jet physics in the complicated RHIC environment.

Successful completion of this detector R&D would almost certainly place LANL to lead the construction of a major state-of-art detector component at RHIC and also elsewhere. It certainly would be an incredibly valuable technology for the Electron-Ion Collider (EIC) that was identified in the 2015 Nuclear Science Advisory Committee (NSAC) Long Range Plan as the highest priority for new facility construction in nuclear science in the United States. I led this Long Range Plan as the Chair of NSAC and I can assure you of the commitment of the community to both the heavy ion and the EIC science.

The LANL groups have demonstrated the scientific and technical skills necessary to carry out this R&D in both the experimental and theoretical areas. They are among the world leaders in heavy quark physics in the quark-gluon plasma. The synergy of the two efforts will ensure the focus on the optimum science goals.

This LDRD project will be exceptionally valuable for LANL, nuclear science, and the nation.

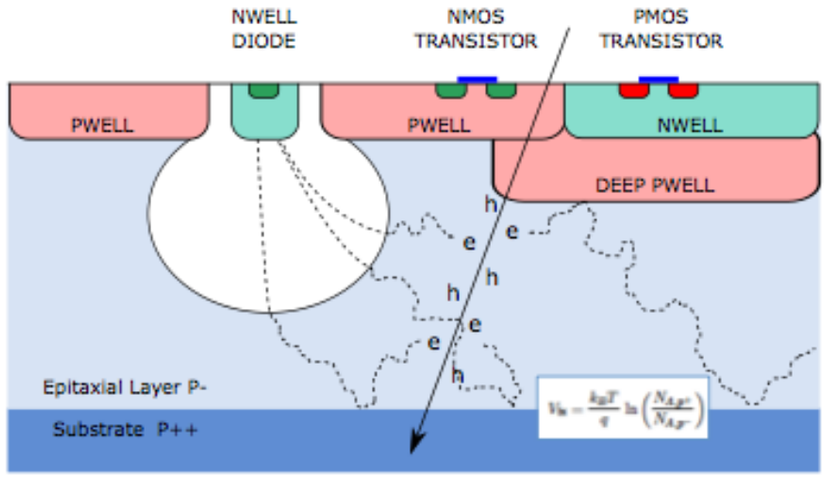
Sincerely,

Donald F. Geesaman

**"This LDRD project will be exceptionally valuable for LANL, nuclear science, and the nation."**
**~ Donald Geesaman, NSAC**

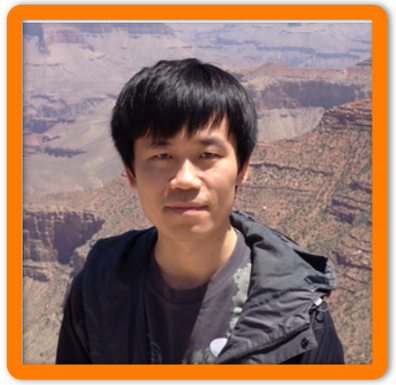
# LANL's Experimental Expertise

## Customize MAPS technology for sPHENIX




**Physicists & Engineers supported under this DR proposal;**
**more expertise from FVTX and Fermilab Projs.**

Tracking, EMCal, HCAL contrib.
sPHENIX / fsPHENIX detector design, jet physics, software
sPHENIX tracking simulation
sPHENIX inner silicon R&D



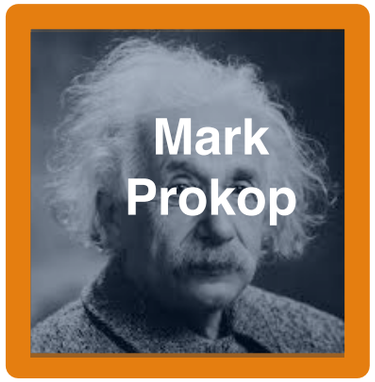
Simulation
offline reconstruction

sPHENIX inner silicon
fsPHENIX & EIC physics

sPHENIX inner silicon
fsPHENIX detector design

sPHENIX inner silicon & electronics

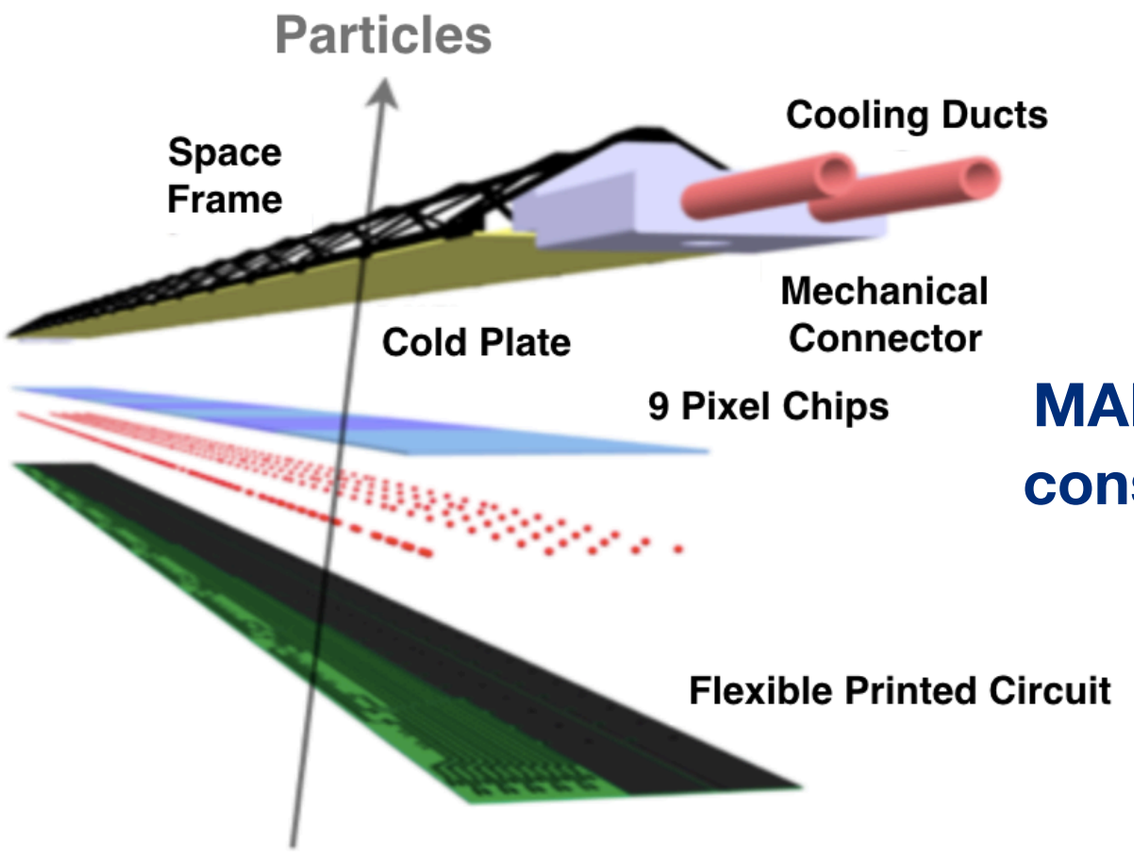
Mechanical Engineering, Magnetic Field & Cooling etc.




Electrical Engineering
Readout Electronics Design, FVTX

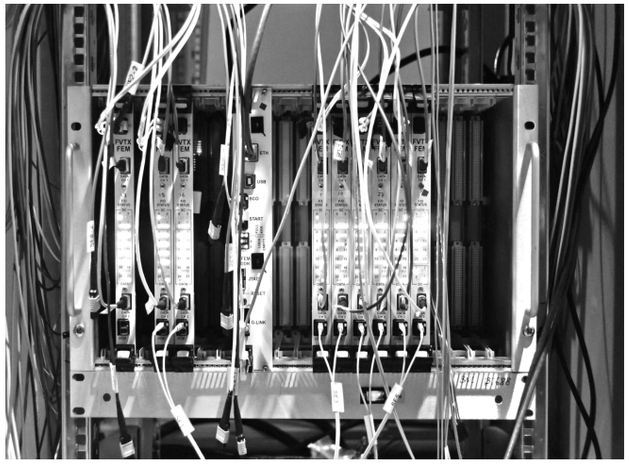
# R&D Deliverable: a Prototype Tracker

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




**MAPS stave construction**

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

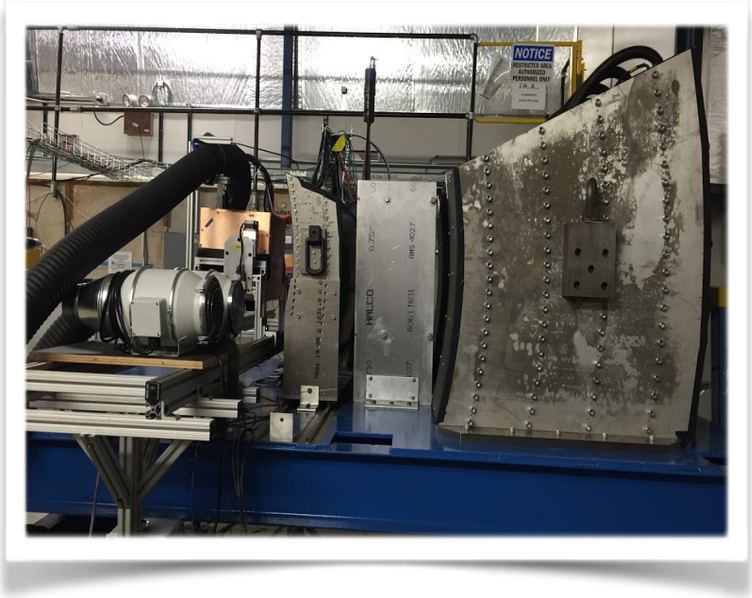


**Custom front end, integrate into sPHENIX readout (FVTX expertise)**

**Annual Fermilab Test beam**

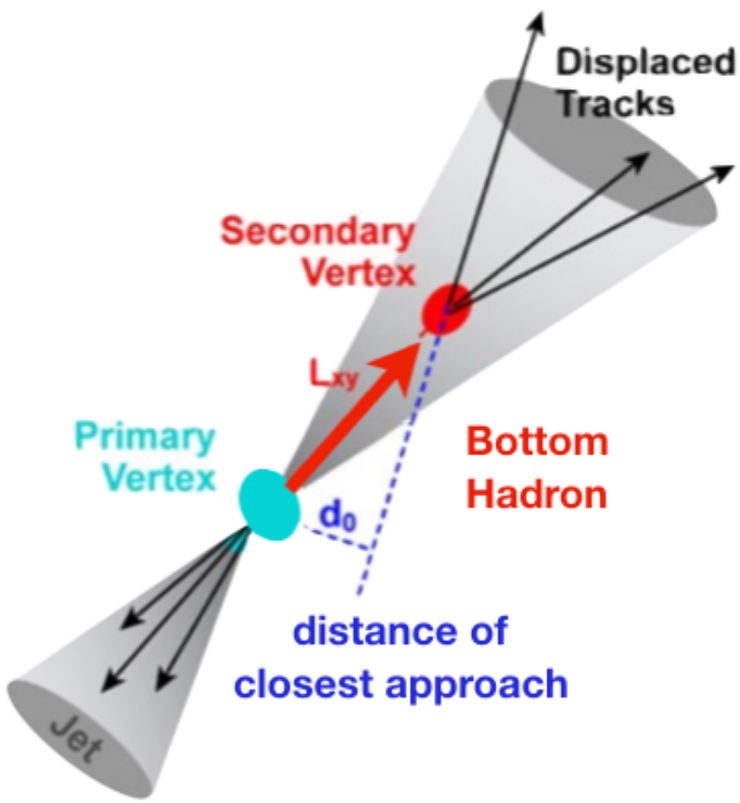
Test prototype tracker

Validate tracking and reconstruction

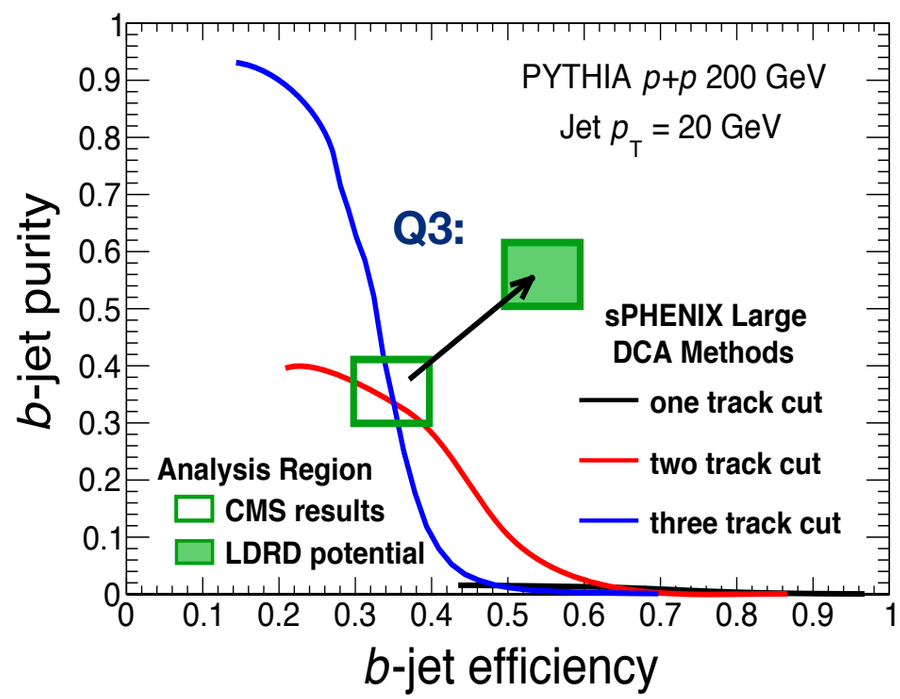


# Experimental R&D Deliverables: Physics

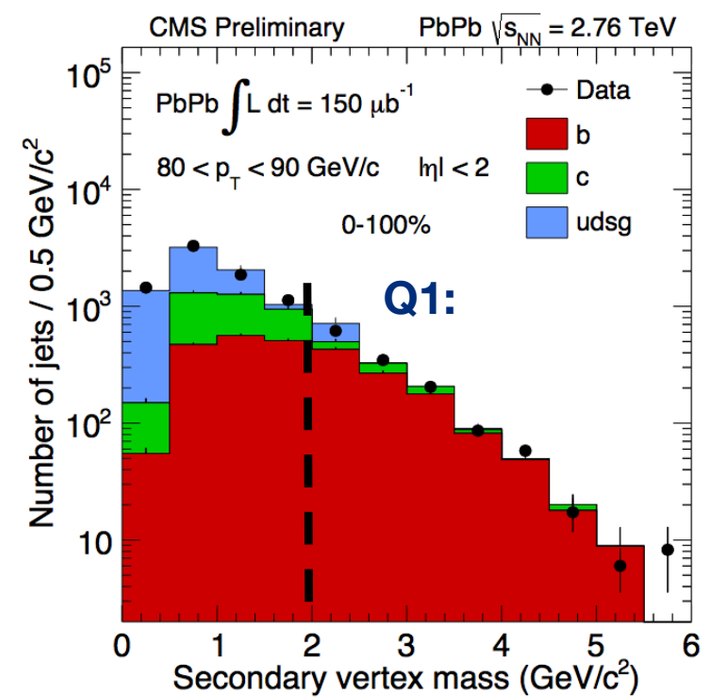
## LDRD Experimental Goal: Improved b-jet Identification in Heavy Ion Collisions




### Track-Counting




### Secondary Vertexing




- 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, **big improvement in FOM**

# B-jet Theory Effort and Innovation

**LDRD Theoretical Goal:** ***develop the most accurate description of b-jet observables in heavy ion collisions; use b-jets as precision diagnostics of the QGP***

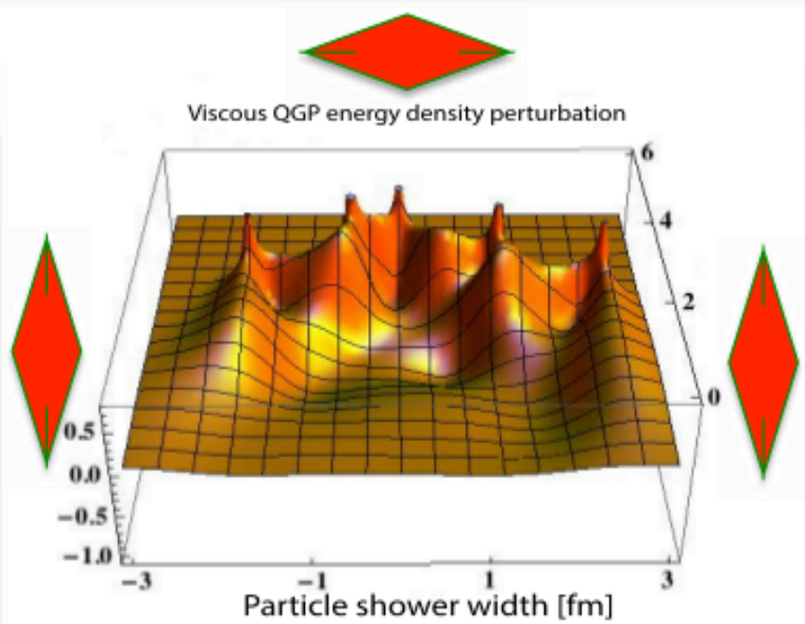
SCET, jets, resummation, p+p

pQCD, b-jets heavy flavor, substructure

MD simulations, strongly-coupled plasmas

***Perturbative QCD/SCET and jet simulations***: most precise b-jet theory in proton collisions, new theory for heavy ion collisions, b-jet substructure, b-jet tomography of the QGP

***QMD simulations:*** transport properties of plasmas, stopping power for heavy particles




***Lattice QCD:*** EoS, input for hydro, charge number fluctuations near the phase transition

***Experiment:*** Tracker design, prototype construction, jet finder development, ongoing and improved PHENIX and STAR BES II analyses

Energy loss, b-jets, HIC, tomography

Lattice QCD, EoS, charge fluctuations

Lattice QCD, large-scale simulations

**Key advancements in several intersecting areas of physics. Theory is an important component.**

# Projected Future sPHENIX Schedule

Slide from Ed O'Brien 6/24/2016

| | |
|---|---|
| **CD-0** | **Sept-Oct 2016** |
| **Director's Cost and Schedule Review** | **Late Fall 2016** |
| **Test Beam at FNAL(2nd round prototyping)** | **Jan 2017** |
| **OPA-CD-1/CD-3a Review** | **May-Jun 2017** |
| **CD-1/CD-3a authorization** | **Nov 2017** |
| **All Preproduction R&D and Design complete** | **May-Jun 2018** |
| **OPA- CD-2/CD-3b review** | **May-Jun 2018** |
| **CD-2/CD-3b authorization** | **Jul-Aug 2018** |
| **sPHENIX Installed, cabled, ready to commission** | **Apr 2021** |
| **First RHIC beam for sPHENIX** | **Jan 2022** |

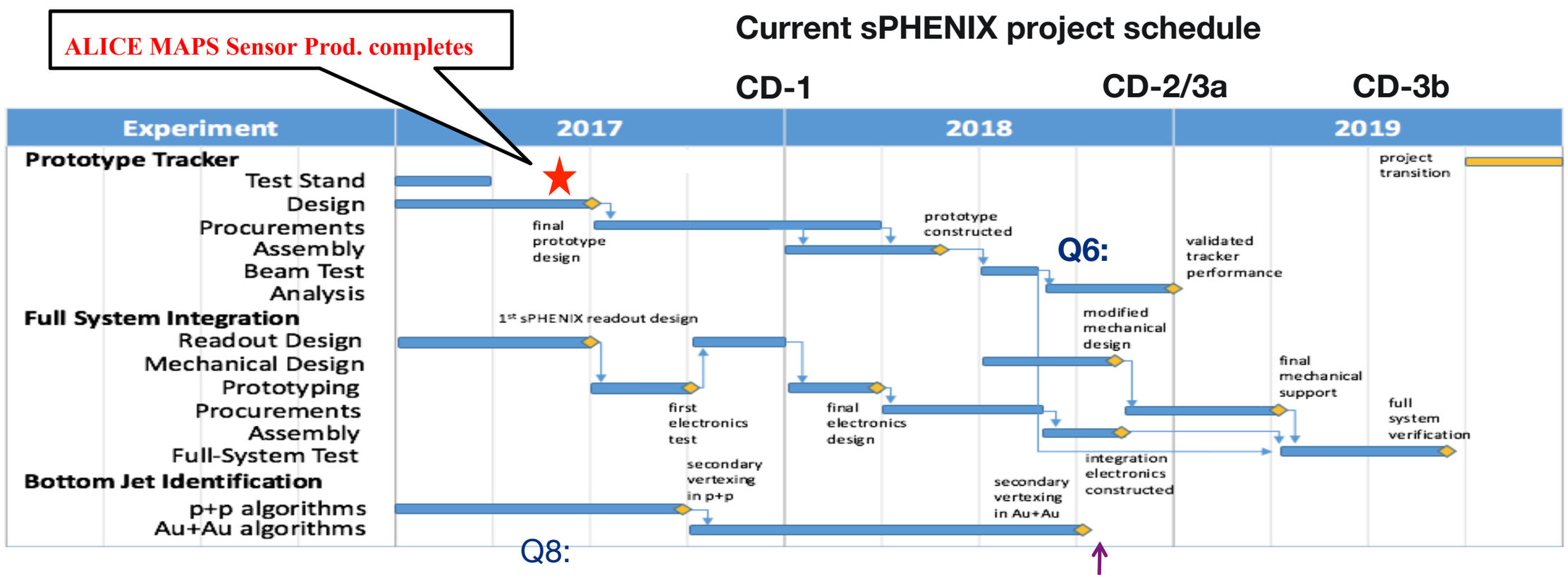
**The current Resource-loaded Schedule contains 8.5 months of float to Jan 2022**

# Cost and Schedule: LDRD

## Crucial R&D for sPHENIX CD-1,X

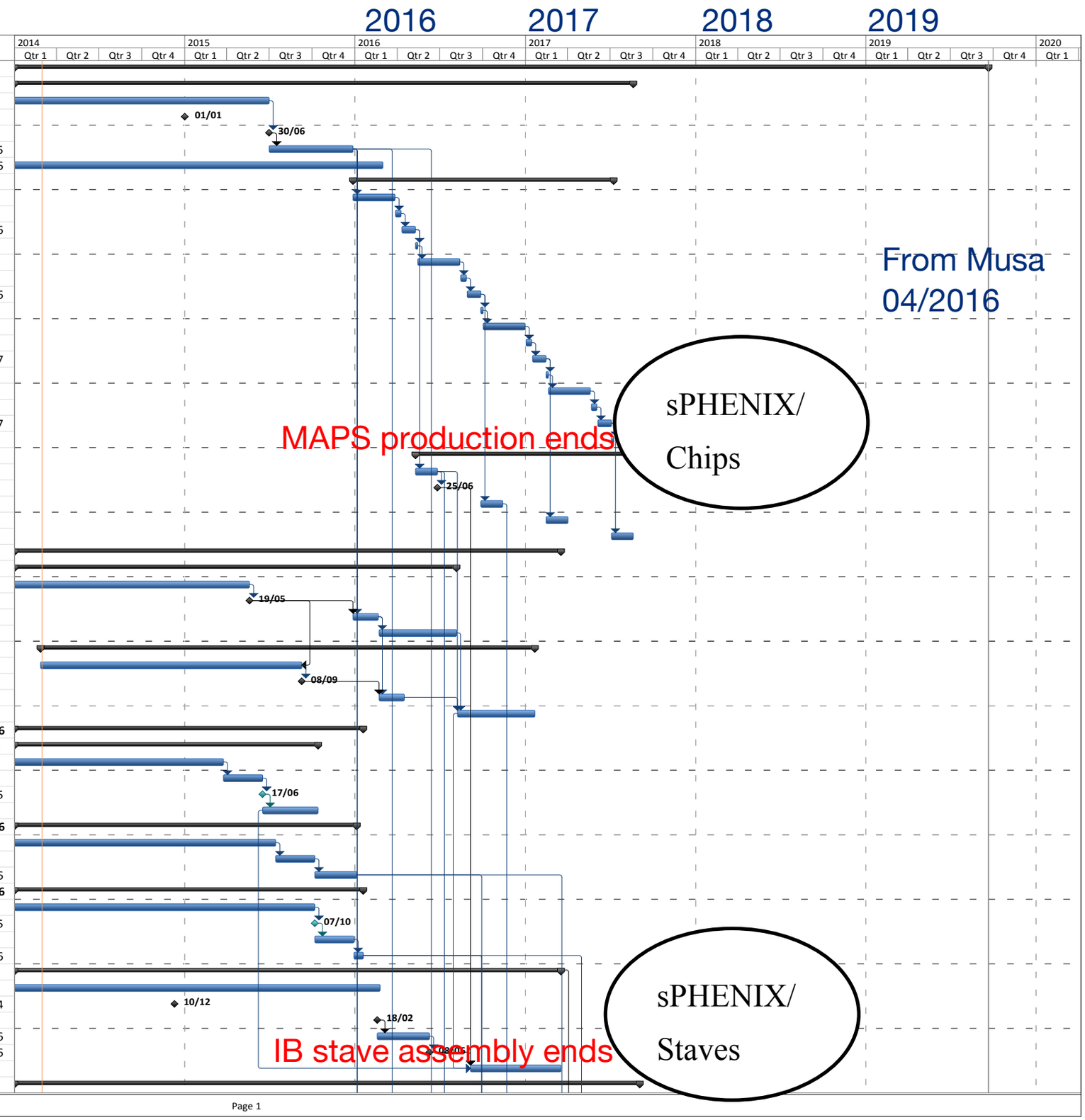
- MAPS sensors for sPHENIX inner tracker R&D by mid 2018, $200K
- 4 fully assembled staves for system test, by mid 2018, $200K
- R&D for MAPS readout and integration, $300K
- Mechanical design and optimization, $150K

**To minimize the technical risk and delay in obtaining the key MAPS chips, we propose to piggyback on the ALICE ITS production in 2017**



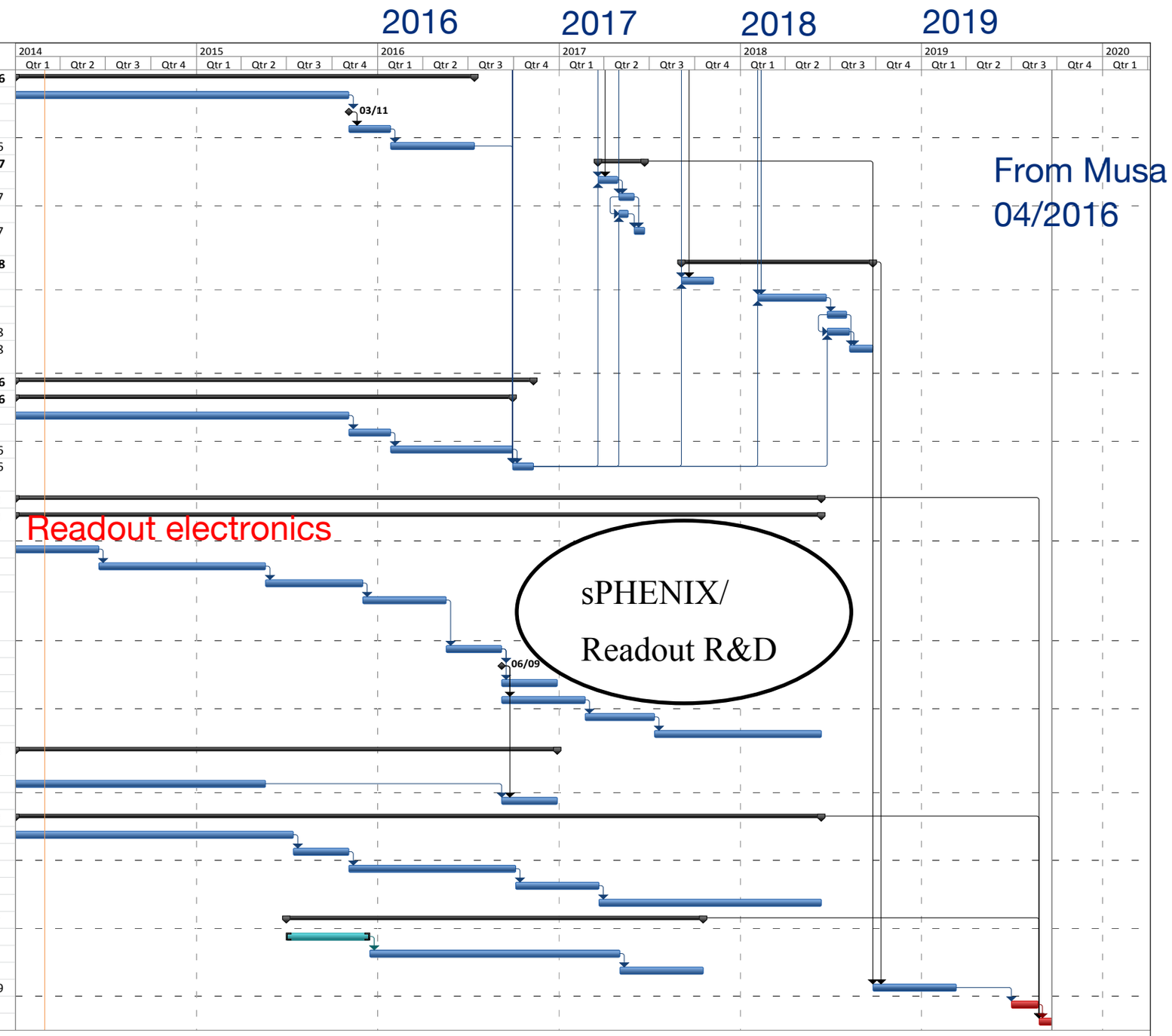
# Updated ALICE ITS/IB Schedule

| ID | WBS | Task Name | Duration | Start | Finish |
|---|---|---|---|---|---|
| 1 | **1** | **ITS UPGRADE** | **74.65 mons** | **Wed 01/01/14** | **Fri 20/09/19** |
| 2 | **1.1** | **Pixel Sensor** | **47.4 mons** | **Wed 01/01/14** | **Sat 19/08/17** |
| 3 | 1.1.1 | Design | 19.5 mons | Wed 01/01/14 | Tue 30/06/15 |
| 4 | 1.1.2 | Design review and architecture selection | 0 days | Thu 01/01/15 | Thu 01/01/15 |
| 5 | 1.1.3 | Production Readines Review | 0 mons | Tue 30/06/15 | Tue 30/06/15 |
| 6 | 1.1.4 | Engineering Run - final design | 6 emons | Wed 01/07/15 | Mon 28/12/15 |
| 7 | 1.1.5 | Characterization of prototype circuits | 28.2 mons | Wed 01/01/14 | Mon 29/02/16 |
| 8 | **1.1.6** | **Production** | **20 mons** | **Mon 28/12/15** | **Sat 08/07/17** |
| 9 | 1.1.6.1 | Lot 1 | 90 edays | Mon 28/12/15 | Sun 27/03/16 |
| 10 | 1.1.6.2 | Wafer Post-processing Lot 1 | 10 days | Mon 28/03/16 | Fri 08/04/16 |
| 11 | 1.1.6.3 | Thinning&Dicing Lot 1 | 21 days | Mon 11/04/16 | Mon 09/05/16 |
| 12 | 1.1.6.4 | Test Lot 1 | 5 edays | Mon 09/05/16 | Sat 14/05/16 |
| 13 | 1.1.6.5 | Lot 2 | 90 edays | Sat 14/05/16 | Fri 12/08/16 |
| 14 | 1.1.6.6 | Wafer Post-processing Lot 2 | 10 days | Mon 15/08/16 | Fri 26/08/16 |
| 15 | 1.1.6.7 | Thinning&Dicing Lot 2 | 21 days | Mon 29/08/16 | Mon 26/09/16 |
| 16 | 1.1.6.8 | Test Lot 2 | 5 edays | Mon 26/09/16 | Sat 01/10/16 |
| 17 | 1.1.6.9 | Lot 3 | 90 edays | Sat 01/10/16 | Fri 30/12/16 |
| 18 | 1.1.6.10 | Wafer Post-processing Lot 3 | 10 days | Mon 02/01/17 | Fri 13/01/17 |
| 19 | 1.1.6.11 | Thinning&Dicing Lot 3 | 21 days | Mon 16/01/17 | Mon 13/02/17 |
| 20 | 1.1.6.12 | Test Lot 3 | 5 edays | Mon 13/02/17 | Sat 18/02/17 |
| 21 | 1.1.6.13 | Lot 4 | 90 edays | Sat 18/02/17 | Fri 19/05/17 |
| 22 | 1.1.6.14 | Wafer Post-processing Lot 4 | 10 days | Mon 22/05/17 | Fri 02/06/17 |
| 23 | 1.1.6.15 | Thinning&Dicing Lot 4 | 21 days | Mon 05/06/17 | Mon 03/07/17 |
| 24 | 1.1.6.16 | Test Lot 4 | 5 edays | Mon 03/07/17 | Sat 08/07/17 |
| 25 | **1.1.7** | **Pixel Chip Testing** | **16.7 mons** | **Mon 09/05/16** | **Sat 19/08/17** |
| 26 | 1.1.7.1 | Test Lot 1 | 47 edays | Mon 09/05/16 | Sat 25/06/16 |
| 27 | 1.1.7.2 | First Lot Ready for Assembly | 0 mons | Sat 25/06/16 | Sat 25/06/16 |
| 28 | 1.1.7.3 | Test Lot 2 | 47 edays | Mon 26/09/16 | Sat 12/11/16 |
| 29 | 1.1.7.4 | Test Lot 3 | 47 edays | Mon 13/02/17 | Sat 01/04/17 |
| 30 | 1.1.7.5 | Test Lot 4 | 47 edays | Mon 03/07/17 | Sat 19/08/17 |
| 31 | **1.2** | **Inner Layer** | **41.9 mons** | **Wed 01/01/14** | **Fri 17/03/17** |
| 32 | **1.2.1** | **Flexible Printed Circuit (FPC)** | **33.9 mons** | **Wed 01/01/14** | **Fri 05/08/16** |
| 33 | 1.2.1.1 | FPC R&D | 18 mons | Wed 01/01/14 | Tue 19/05/15 |
| 34 | 1.2.1.2 | FPC Final Design Review | 0 mons | Tue 19/05/15 | Tue 19/05/15 |
| 35 | 1.2.1.3 | FPC - Pre-series with Final Design | 2 mons | Mon 28/12/15 | Fri 19/02/16 |
| 36 | 1.2.1.4 | FPC PRODUCTION | 6 mons | Mon 22/02/16 | Fri 05/08/16 |
| 37 | **1.2.2** | **Hybrid Integrated Circuit (HIC)** | **37.9 mons** | **Wed 26/02/14** | **Fri 20/01/17** |
| 38 | 1.2.2.1 | HIC R&D | 20 mons | Wed 26/02/14 | Tue 08/09/15 |
| 39 | 1.2.2.2 | HIC Final Design Review | 0 mons | Tue 08/09/15 | Tue 08/09/15 |
| 40 | 1.2.2.3 | HIC Final Module Building | 2 mons | Mon 22/02/16 | Fri 15/04/16 |
| 41 | 1.2.2.4 | HIC Production and Test | 120 days | Mon 08/08/16 | Fri 20/01/17 |
| 42 | **1.2.3** | **Inner Layer mechanics & Cooling** | **26.7 mons** | **Wed 01/01/14** | **Mon 18/01/16** |
| 43 | **1.2.3.1** | **Space Frame and Cold Plate** | **23.25 mons** | **Wed 01/01/14** | **Tue 13/10/15** |
| 44 | 1.2.3.1.1 | R&D | 16 mons | Wed 01/01/14 | Tue 24/03/15 |
| 45 | 1.2.3.1.2 | Pre-Series | 3 mons | Wed 25/03/15 | Tue 16/06/15 |
| 46 | 1.2.3.1.3 | Production Readiness Review | 0 mons | Wed 17/06/15 | Wed 17/06/15 |
| 47 | 1.2.3.1.4 | Production & Test | 85 days | Wed 17/06/15 | Tue 13/10/15 |
| 48 | **1.2.3.2** | **Endwheels** | **26.2 mons** | **Wed 01/01/14** | **Mon 04/01/16** |
| 49 | 1.2.3.2.1 | R&D | 20 mons | Wed 01/01/14 | Tue 14/07/15 |
| 50 | 1.2.3.2.2 | Pre-Series | 3 mons | Wed 15/07/15 | Tue 06/10/15 |
| 51 | 1.2.3.2.3 | Production & Test | 64 days | Wed 07/10/15 | Mon 04/01/16 |
| 52 | **1.2.3.3** | **Inner Cylindrical Structural Shell** | **26.7 mons** | **Wed 01/01/14** | **Mon 18/01/16** |
| 53 | 1.2.3.3.1 | R&D | 23 mons | Wed 01/01/14 | Tue 06/10/15 |
| 54 | 1.2.3.3.2 | Design Review | 0 mons | Wed 07/10/15 | Wed 07/10/15 |
| 55 | 1.2.3.3.3 | Qualification Module | 3 mons | Wed 07/10/15 | Tue 29/12/15 |
| 56 | 1.2.3.3.4 | Production & Test | 14 days | Wed 30/12/15 | Mon 18/01/16 |
| 57 | 1.2.4 | Stave Assembly & test | 41.9 mons | Wed 01/01/14 | Fri 17/03/17 |
| 58 | 1.2.4.1 | R&D | 28 mons | Wed 01/01/14 | Tue 23/02/16 |
| 59 | 1.2.4.2 | Full-scale prototype 1 | 0 mons | Wed 10/12/14 | Wed 10/12/14 |
| 60 | 1.2.4.3 | Full-Scale Prototype with Final Components | 0 mons | Thu 18/02/16 | Thu 18/02/16 |
| 61 | 1.2.4.4 | Final Desfin and Prototype | 4 mons | Thu 18/02/16 | Wed 08/06/16 |
| 62 | 1.2.4.5 | Production Readiness Review | 0 mons | Wed 08/06/16 | Wed 08/06/16 |
| 63 | 1.2.4.6 | Production and Test (120 staves) | 7 mons | Mon 05/09/16 | Fri 17/03/17 |
| 64 | **1.3** | **Middle Layer** | **47.9 mons** | **Wed 01/01/14** | **Sat 02/09/17** |



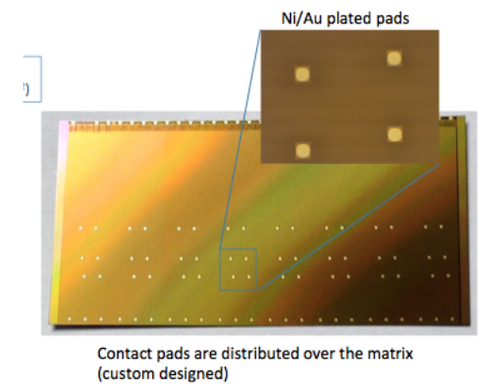
# Updated ALICE ITS Electronics Schedule

| ID | WBS | Task Name | Duration | Start | Finish |
|---|---|---|---|---|---|
| 129 | **1.5.2** | **Outer Service Barrel** | **33.05 mons** | **Wed 01/01/14** | **Wed 13/07/16** |
| 130 | 1.5.2.1 | R&D | 24 mons | Wed 01/01/14 | Tue 03/11/15 |
| 131 | 1.5.2.2 | Design Review | 0 mons | Tue 03/11/15 | Tue 03/11/15 |
| 132 | 1.5.2.3 | Qualification Module | 3 mons | Wed 04/11/15 | Tue 26/01/16 |
| 133 | 1.5.2.4 | Production & Test | 121 days | Wed 27/01/16 | Wed 13/07/16 |
| 134 | **1.5.3** | **Inner Barrel** | **3.4 mons** | **Mon 20/03/17** | **Wed 21/06/17** |
| 135 | 1.5.3.1 | Inner Layers Assembly | 30 days | Mon 20/03/17 | Fri 28/04/17 |
| 136 | 1.5.3.2 | Detector Barrel Assembly | 23 days | Mon 01/05/17 | Wed 31/05/17 |
| 137 | 1.5.3.3 | Service Barrel Assembly | 15 days | Mon 01/05/17 | Fri 19/05/17 |
| 138 | 1.5.3.4 | Detector Barrel and Service Barrel Integration | 15 days | Thu 01/06/17 | Wed 21/06/17 |
| 139 | **1.5.4** | **Outer Barrel** | **13.8 mons** | **Mon 04/09/17** | **Mon 24/09/18** |
| 140 | 1.5.4.1 | Middle Layers Assembly | 47 days | Mon 04/09/17 | Tue 07/11/17 |
| 141 | 1.5.4.2 | Outer Layers Assembly | 100 days | Mon 05/02/18 | Fri 22/06/18 |
| 142 | 1.5.4.3 | Detector Barrel Assembly | 29 days | Mon 25/06/18 | Thu 02/08/18 |
| 143 | 1.5.4.4 | Service Barrel Assembly | 33 days | Mon 25/06/18 | Wed 08/08/18 |
| 144 | 1.5.4.5 | Detector Barrel and Service Barrel Integration | 33 days | Thu 09/08/18 | Mon 24/09/18 |
| 145 | **1.6** | **Integration in ALICE** | **37.3 mons** | **Wed 01/01/14** | **Wed 09/11/16** |
| 146 | **1.6.1** | **Cage + Installation Mechanics** | **35.8 mons** | **Wed 01/01/14** | **Wed 28/09/16** |
| 147 | 1.6.1.1 | R&D | 24 mons | Wed 01/01/14 | Tue 03/11/15 |
| 148 | 1.6.1.2 | Qualification Module | 3 mons | Wed 04/11/15 | Tue 26/01/16 |
| 149 | 1.6.1.3 | Production & Test | 176 days | Wed 27/01/16 | Wed 28/09/16 |
| 150 | 1.6.2 | Insertion Test with all Final Support Structures (without detector) | 1.5 mons | Thu 29/09/16 | Wed 09/11/16 |
| 151 | **1.7** | **Readout Electronics** | **58 mons** | **Wed 01/01/14** | **Tue 12/06/18** |
| 152 | **1.7.1** | **Readout Unit (readout board 5m from detector)** | **58 mons** | **Wed 01/01/14** | **Tue 12/06/18** |
| 153 | 1.7.1.1 | Specifications | 6 mons | Wed 01/01/14 | Tue 17/06/14 |
| 154 | 1.7.1.2 | Readout Unit ver. 1 | 12 mons | Wed 18/06/14 | Tue 19/05/15 |
| 155 | 1.7.1.3 | Readout Unit vers. 2 | 7 mons | Wed 20/05/15 | Tue 01/12/15 |
| 156 | 1.7.1.4 | Test of complete readout chain (front-end, e-links, readout unit, common readout unit and trigger interface) | 6 mons | Wed 02/12/15 | Tue 17/05/16 |
| 157 | 1.7.1.5 | Readout Unit vers. 3 | 4 mons | Wed 18/05/16 | Tue 06/09/16 |
| 158 | 1.7.1.6 | Production Readiness Review | 0 mons | Tue 06/09/16 | Tue 06/09/16 |
| 159 | 1.7.1.7 | Market survey and tendering | 4 mons | Wed 07/09/16 | Tue 27/12/16 |
| 160 | 1.7.1.8 | Readout Unit final version | 6 mons | Wed 07/09/16 | Tue 21/02/17 |
| 161 | 1.7.1.9 | Pre-series production | 5 mons | Wed 22/02/17 | Tue 11/07/17 |
| 162 | 1.7.1.10 | Production and test (220 boards) | 12 mons | Wed 12/07/17 | Tue 12/06/18 |
| 163 | **1.7.2** | **E-links (electrical links between detector stave and Readout Unit)** | **39 mons** | **Wed 01/01/14** | **Tue 27/12/16** |
| 164 | 1.7.2.1 | R&D | 18 mons | Wed 01/01/14 | Tue 19/05/15 |
| 165 | 1.7.2.2 | Procurement (336 cables) | 4 mons | Wed 07/09/16 | Tue 27/12/16 |
| 166 | **1.8** | **Power Distribution** | **58 mons** | **Wed 01/01/14** | **Tue 12/06/18** |
| 167 | 1.8.1 | R&D | 20 mons | Wed 01/01/14 | Tue 14/07/15 |
| 168 | 1.8.2 | Specifications | 4 mons | Wed 15/07/15 | Tue 03/11/15 |
| 169 | 1.8.3 | Qualification of LV Power Delivery Network | 12 mons | Wed 04/11/15 | Tue 04/10/16 |
| 170 | 1.8.4 | Market survey and Tendering | 6 mons | Wed 05/10/16 | Tue 21/03/17 |
| 171 | 1.8.5 | Procurment | 16 mons | Wed 22/03/17 | Tue 12/06/18 |
| 172 | **1.9** | **Cooling Plant** | **30 mons** | **Wed 01/07/15** | **Tue 17/10/17** |
| 173 | 1.9.1 | Conceptual design and specifications | 6 mons | Wed 01/07/15 | Tue 15/12/15 |
| 174 | 1.9.2 | Development and construction | 18 mons | Wed 16/12/15 | Tue 02/05/17 |
| 175 | 1.9.3 | Commissioning | 6 mons | Wed 03/05/17 | Tue 17/10/17 |
| 176 | 1.10 | **Commissioning at surface** | 6 mons | Tue 25/09/18 | Mon 11/03/19 |
| 177 | 1.11 | **Installation** | 8 wks | Mon 01/07/19 | Fri 23/08/19 |
| 178 | 1.12 | **Commissioning in ALICE** | 4 wks | Mon 26/08/19 | Fri 20/09/19 |



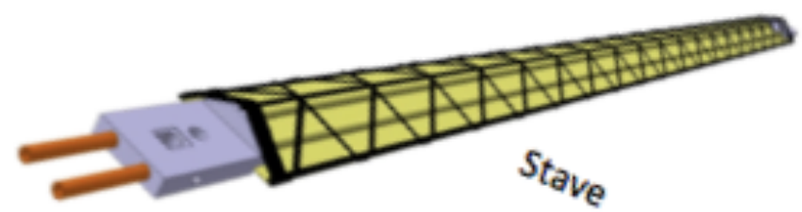
# Summary: LDRD Hardware Deliverables

**Extend TowerJazz Production:**
- In-kind contribution
- 525 ALPIDE-final sensors
- (inner 3 layers plus ~20% spares)




525 ct.

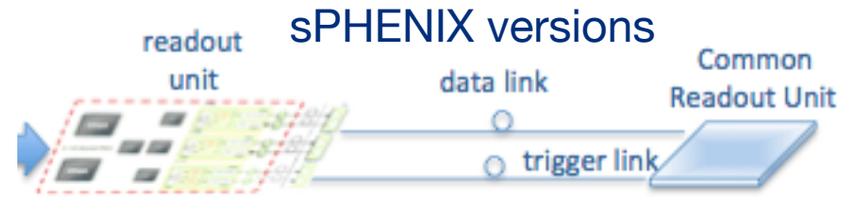
**Test Beam Prototype:**
- 4 full inner ALICE ITS Staves
- ALICE readout + common readout boards
- small scale power & cooling, jigs, etc




4 ct.

**Readout Design:**
- new FEM design for sPHENIX,
- replace the ALICE readout board
- full-system test with test beam prototype

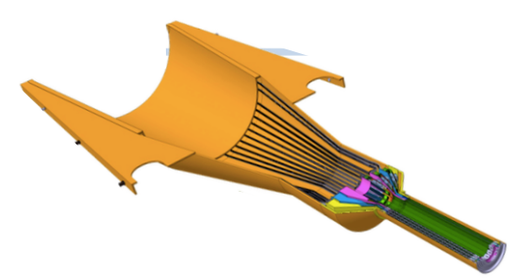
sPHENIX versions




4 ct.

**Half-Barrel Mechanical Design:**
- adapt ALICE inner 3 layer mechanics to sPHENIX
- build 3-layer mounts for full-system test

sPHENIX versions



2 ct.

**Under LDRD funding:**
- **Final Detector ~10% populated with staves & readout**
- **CERN-trained personnel**
- **Reduce cost of MAPS detector by $2M!**

# Electronics R&D @LANL

- Obtained latest ALPIDE-3 at LANL
- R&D lab through LANL fund
  - To setup sPHENIX DAQ/DCM-II
  - MAPS readout integration
  - Reuse FVTX FEMS?
  - And more

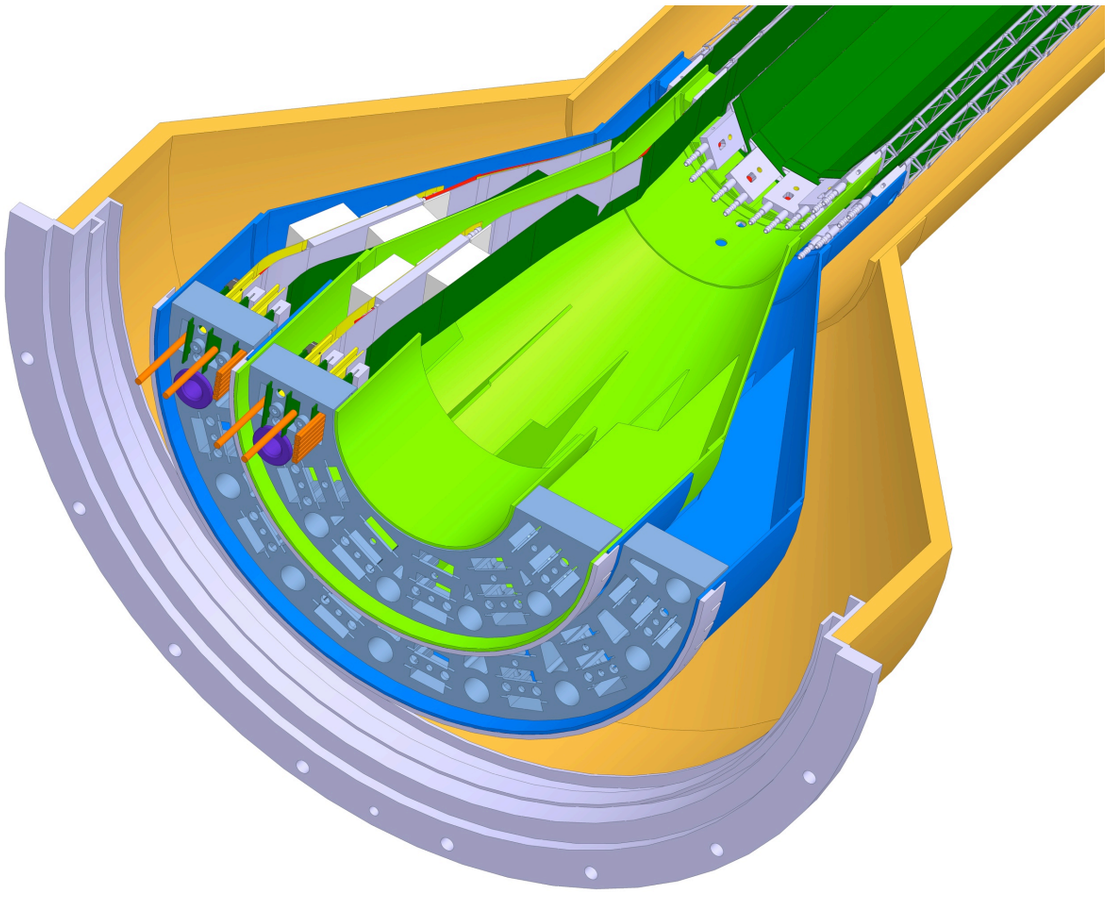
**1st MAPS prototype sensor** being studied at **LANL**

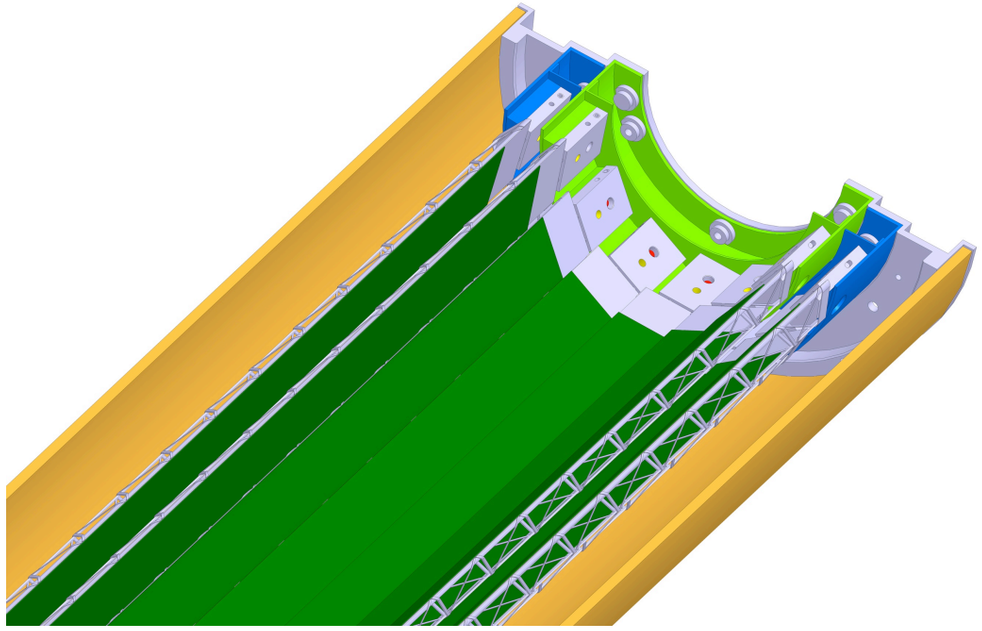
LBNL R&D expert visited LANL May 2-4th

Mike's expertise on DCM-II

# Mechanical R&D @LANL

- Walt obtained CAD design from ALICE
  - 3 layers vs 2 layers options
- Physics + detector simulations for optimization
  - Pile-up, matching etc.





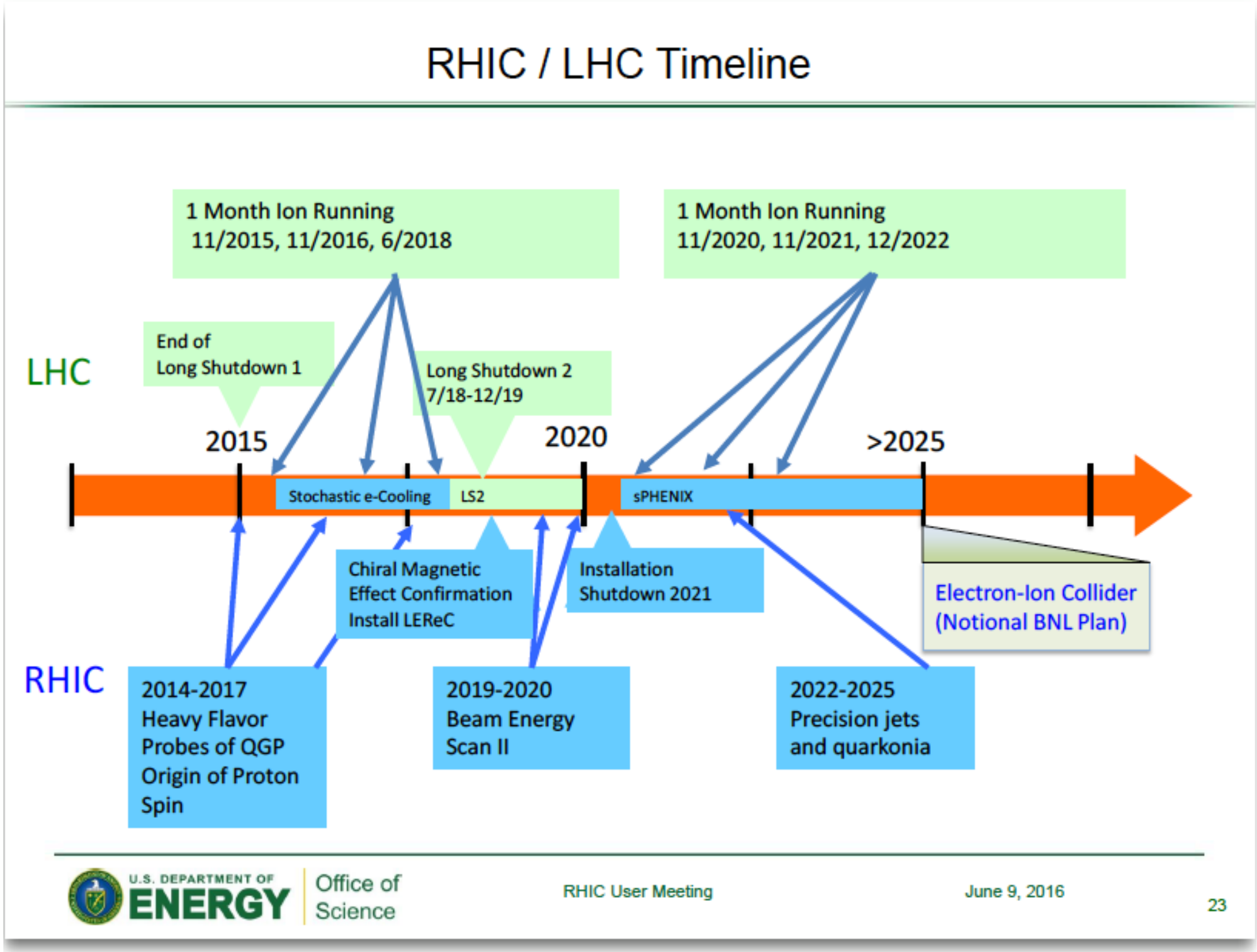
# Building Collaboration

- Workshops organized in Santa Fe
  - Experts on MAPS
- ALICE MAPS group
  - Strong support from Musa et al at CERN
  - Yonsei / Korean Institutions
  - LBNL
- Locals
  - UNM, NMSU, other (s)PHENIX institutions
  - MIT ME group
  - STAR/HFT group
  - LBNL, LDRD proposal to build mechanical support
- Other international collaborators

# Summer Work and Beyond

- LDRD decision ~7/7
  - LDRD: 10/2016-9/2019
  - But what if ….
- MAPS test and integration @LANL
  - Standalone sPHENIX DAQ/DCM-II
  - MAPS readout R&D
- Update C&S for September 7-9 review
- BNL sPHENIX tracker review (Nov. 2016?)
- sPHENIX MAPS full proposal
  - Build collaboration
  - Simulation and detector optimizatoin
  - Full detector design, CD-1
  - Plan for construction

# DOE's View on sPHENIX and other Long Term NP




from Tim Hallman's talk at RHIC Users' Meeting, June 2016