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Muon g-2 Project

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Fermilab Institutional Review

12 February 2015

Outline

- Project status and organization
- Scope and progress to date
- Cost and schedule
- Project personnel
- Integration of project and scientific collaboration

Context

- Muon g-2 provides a compelling opportunity to mount a next generation experiment at FNAL
  - Next proton beam based particle physics experiment to be constructed after NOvA and MicroBooNE
- Synergistic part of the overall muon program at FNAL
- Full cost, schedule, and risk analysis has been performed resulting in a total project cost (TPC) of $46.4M
  - NSF ($3.6M), Early Career Grant ($2.5M), and International In-Kind for design and construction of detectors not included in TPC
  - Schedule achieves beam delivery to experiment by end of Q2FY17
- Many personnel playing large project roles and the project is fully-integrated with the larger scientific collaboration

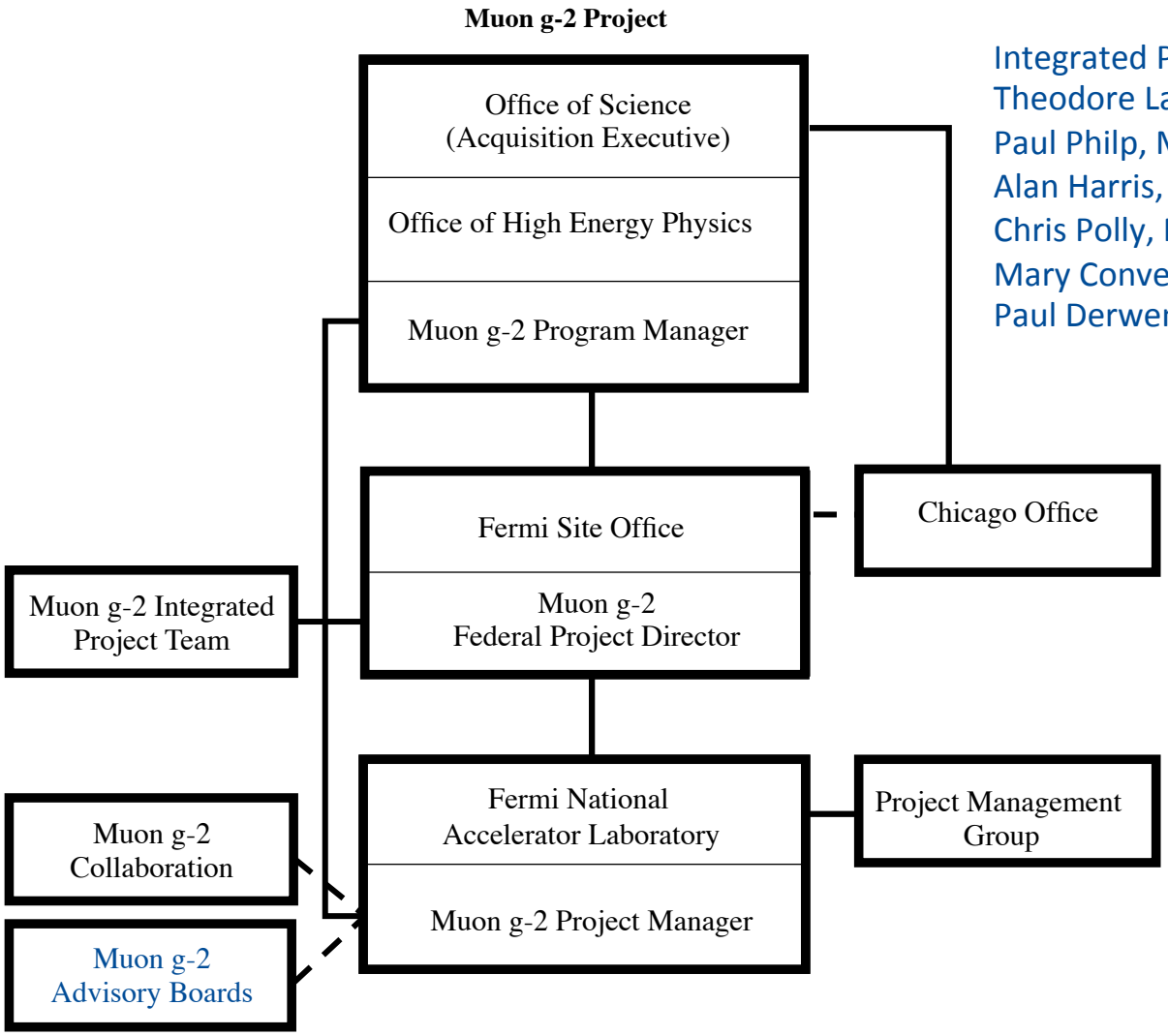
DOE Critical Decision Steps

- Project received CD-0 Approval Sep 18, 2012
  - CD-0 is a statement of mission need and a release of funding required to produce and document a conceptual design
- CD-1 Approval granted Dec 19, 2013
  - CD-1 approval is an approval of the conceptual design (CDR) and release of funding to produce a technical design
- CD-2/3 Review held July 2014
  - CD-2 is approval of technical design (TDR) and funding to start final design, establishes the final TPC and baseline schedule for measuring project performance
  - CD-3 is the approval and release of funds to begin construction

Outcome of CD-2/3 Review

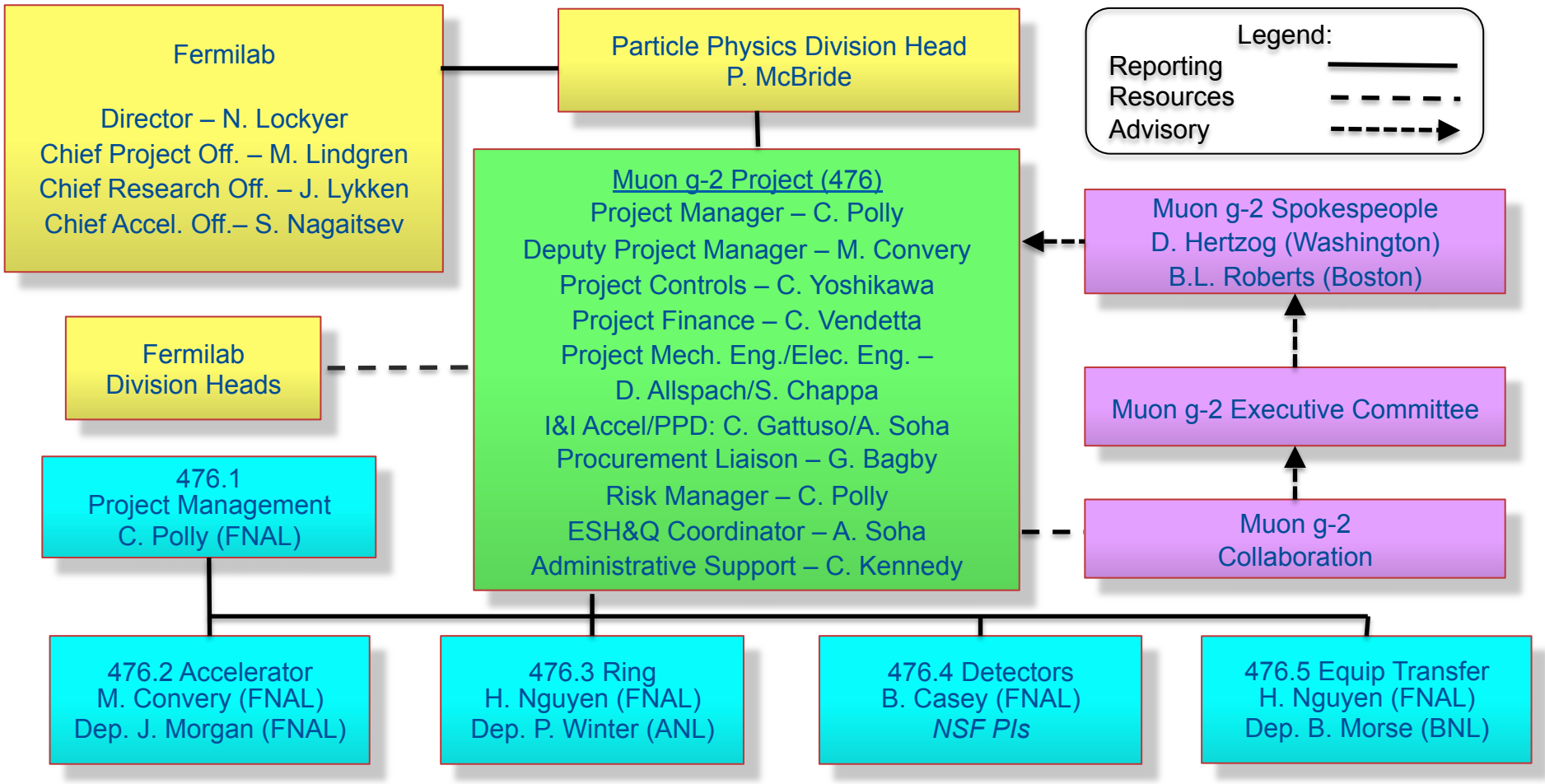
- Recommendation to defer approval until full system test (cold & powered) of BNL storage ring can be demonstrated
  - Agency has had trouble with recycling other superconducting magnets…prudent to demonstrate storage ring functionality prior to baseline
  - Eliminates the largest remaining cost & schedule risk prior to establishing the CD-2/3 approval…gives agency and project more flexibility
- To maintain project critical path, two special interim authorizations were received
  - $2.7M in funding needed to test the storage ring
  - $2.8M in accelerator funding to get started on work that could largely be considered generally useful outside of g-2
  - Other construction funding on hold until ring test complete

DOE Reporting Lines

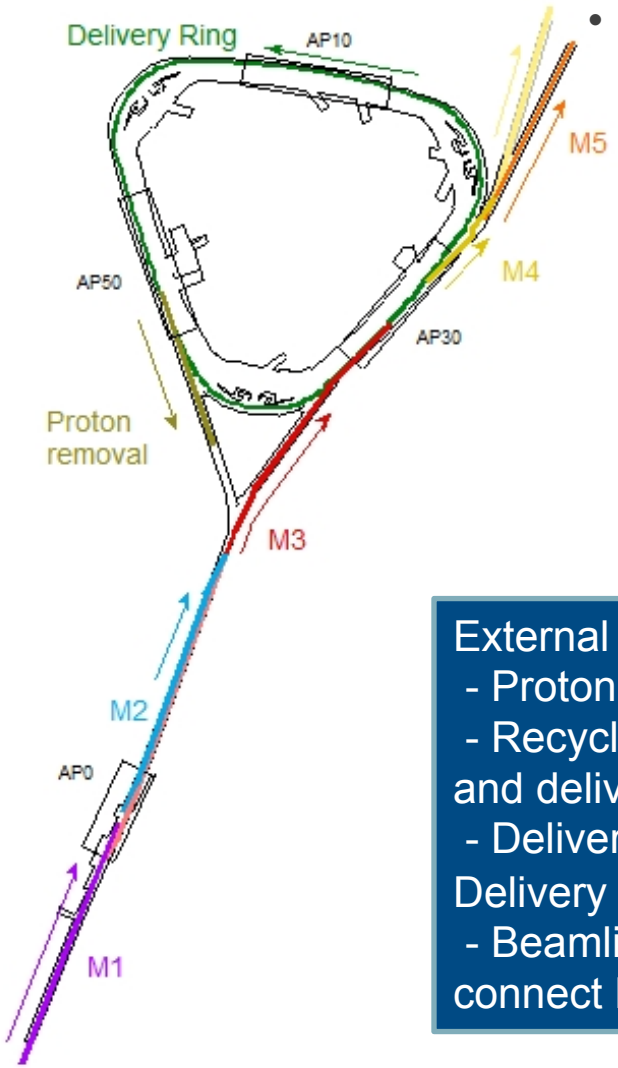


Integrated Project Team:
Theodore Lavine, Muon g-2 Federal Program Manager
Paul Philp, Muon g-2 Federal Project Director, IPT Chair
Alan Harris, Muon g-2 Deputy Federal Project Director
Chris Polly, Muon g-2 Project Manager
Mary Convery, Muon g-2 Deputy Project Manager
Paul Derwent, AD Division Office (NOvA lessons)

Project Organization



WBS 476.2 Accelerator Scope

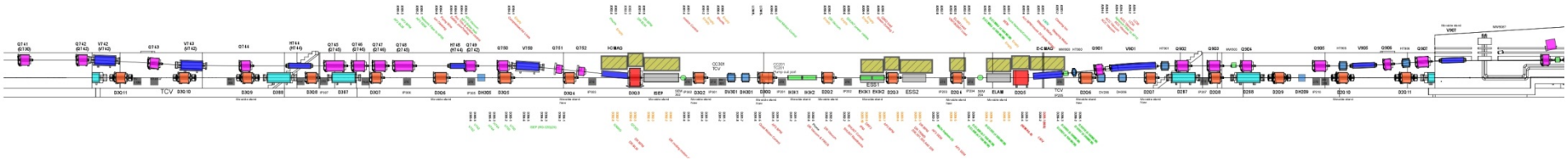


- Convert anti-proton source to a custom muon source
  - Largely reuse of AP0 target hall as-is with some modification and repairs to run at g-2 rep rate
  - Installation of M2, M3, M4, and M5 beamlines to efficiently capture muons and transport to experimental hall
  - Circulation in Delivery Ring for to enough turns (4-7) to remove protons from muon beam
  - Appropriate controls, instrumentation, and safety systems to monitor and steer the beam

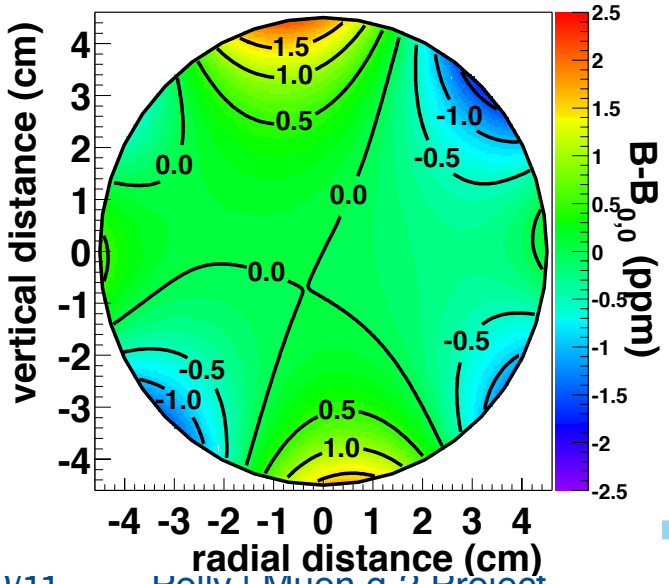
External Dependencies:
- Proton Improvement Plan to upgrade Booster to 15 Hz
- Recycler RF and Beam Transport AIPs rebunch Booster beam and deliver to M1 line
- Delivery Ring AIP providing common g-2/Mu2e components in Delivery Ring
- Beamline Enclosure GPP constructs new tunnel system to connect Delivery Ring to g-2 and Mu2e halls

WBS 476.2 Accelerator Status

- Final design is nearly complete
- Pulse-testing of AP0 Li lens and bending magnet demonstrated at g-2 rep rate… was considered highest risk for accelerator plan at one point
- D30 straight section ready for installation
- Focus with $2.8M special auth
  - Power supply procurements
  - Instrumentation procurements
  - Construction of magnets in TD



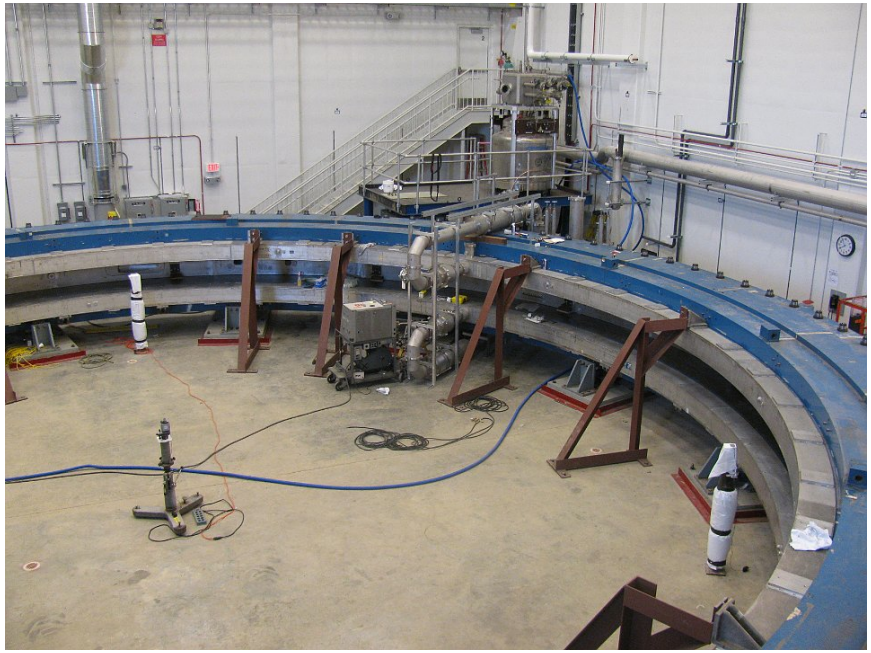
WBS 476.2 Ring Scope



- Reassembly of E821 storage ring and preparation for operation
- Design, construct, and install upgraded subsystems
  - Refurbishment of ring and modernization to FNAL-compatible controls
  - Upgrades to electromagnetic kickers and electrostatic quadrupoles
  - Reuse of superconducting inflector
  - Improvements in field monitoring equipment and shimming of magnetic field to attain high uniformity

External Dependencies (Both complete):
- MC-1 Building GPP to house storage ring
- Muon Campus Cryo Plant to provide liquid He and N cryogens for storage ring and inflector

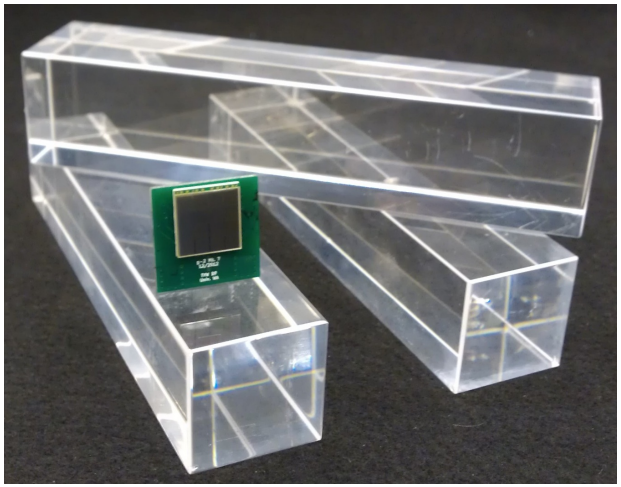
WBS 476.2 Ring Status

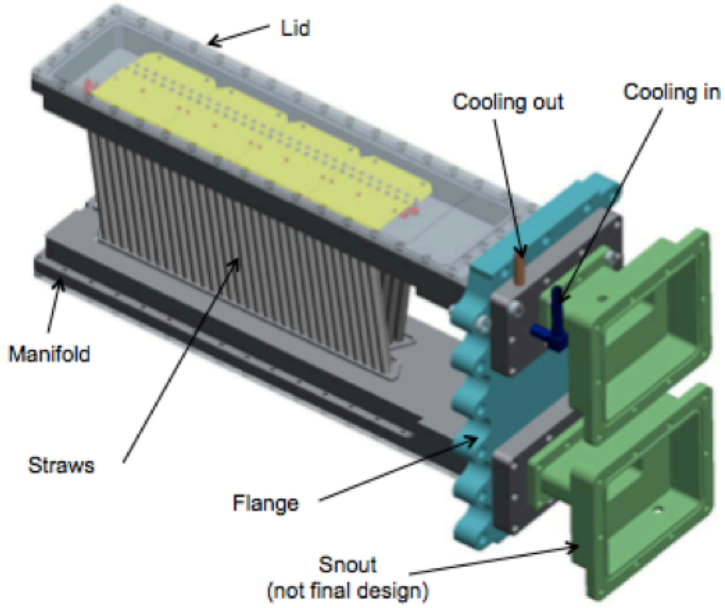


- Ring reassembly
  - Yoke steel assembled and aligned to 125 micron tolerance
  - Cryostat vacuum and cryogen supply lines refurbished and leak-checked
  - PS, quench protection, He dewer, LCW, cable trays, and C&I backplanes installed
- Next steps
  - Alignment of coils (~1mm), installation and alignment (25 micron) of 72 pole pieces
  - Connections…PS, quench, C&I
  - Construction of cryogenic transfer lines
  - Working on repair of 'BNL cold leak'

- Still on schedule to begin cool-down in March and conduct full system test by May
  - Important to maintain schedule that rest of construction funding be released on that timescale with CD-2/3 approval
- In parallel, final design work on kickers, quads, inflector, and magnetic field equipment is proceeding
- Next critical path step for ring WBS will be the 9-12 period of magnetic field shimming

WBS 476.3 Detector Scope





- Calorimeters 24 6x9 PbF2 crystal arrays with SiPM readout
- New electronics and DAQ
- Three 1500 channel straw trackers to precisely monitor properties of stored muon beam via tracking of Michel decay positrons
- Auxiliary detectors and slow controls to monitor beam properties and environmental conditions

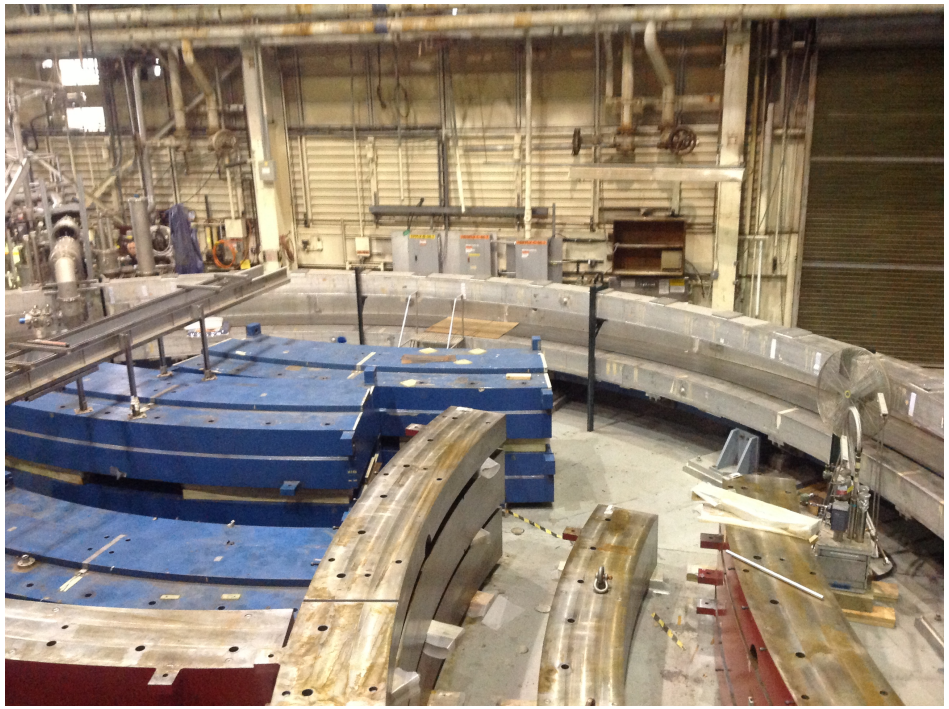
External Dependencies:
- Calorimeters, DAQ, and electronics primarily NSF funded with laser calibration from INFN
- Trackers funded by Early Career and UK contributions

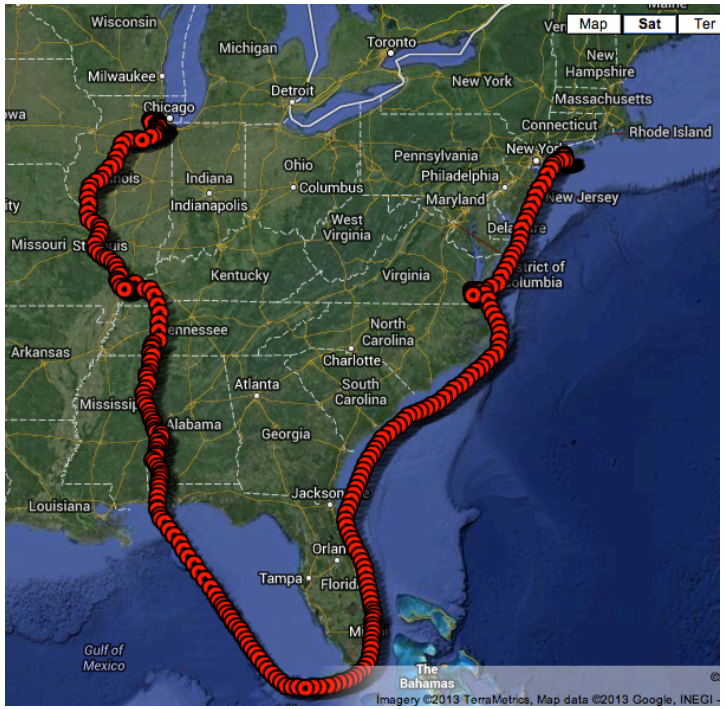
WBS 476.3 Detector Status

- Project
  - Only part that is on-project is slow controls and some auxiliary detectors for monitoring beam injection and dynamics
  - Design nearing completion, looking at adding additional instrumentation to monitor injection profiles around inflector
- Early Career (Straw Trackers)
  - Significant redesign based on preliminary design and lessons learned from last test beam
  - Final design nearing completion with test beam scheduled for June
- NSF MRI
  - Calorimeters, electronics, and DAQ all making good progress
  - Largest procurement of PbF2 crystals well under way (>500 received)
  - Very successful test beam at SLAC with NIM paper published
- International Contributions
  - Large investment in trackers coming from STFC, playing very central role
  - INFN approved for design and construction of laser calibration system

WBS 476.5 Disassembly and Transport Status

- Section of WBS now closed out
  - All equipment disassembled and transported to Fermilab
  - Completed on budget (even compared to 2009 proposal) and ahead of schedule proposed at CD-0
  - Huge success, both technically and from a PR perspective





Transport of the Cryostats from Long Island

- Emmert Int'l did an outstanding job!
- Very successful major procurement effort by laboratory

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Transport of the Cryostats from Long Island

- Transport through Chicago suburbs for 50 ft wide load was no small feat
- Required closure of two interstates

Transport of the Cryostats from Long Island

Many people involved and excited!

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Key Performance Parameters

	Threshold Performance	Objective Performance
Accelerator	All accelerator components of Beamlines M2, M3, M4 and M5 are ready for installation, dependent on external factors. (Installation of Beamline M2 or M3 components requires accelerator shutdown for personnel access, impacting NOvA operations. Installation of Beamline M4 or M5 components requires the Beamline Enclosure GPP.) All other accelerator components are installed and ready for commissioning with beam at nominal voltages and currents, represented by: • Target Station Momentum Selection Magnet (PMAG) Pulsed Power Supply achieving 15.3 kA peak current; • Target Station Lithium Lens Pulsed Power Supply achieving 19 kA peak current; • Delivery Ring Extraction Lambertson Magnet and Power Supply achieving 1.13 Tesla-m integrated field strength; and • Delivery Ring Extraction C-Magnet and Power Supply achieving 1.68 Tesla-m integrated field strength.	All accelerator components are installed and ready for commissioning with beam at nominal voltages and currents.

- KPPs explicitly state the requirements for a project to be considered complete
  - Threshold are the minimum, objective is the goal and what has been costed in TPC

Key Performance Parameters

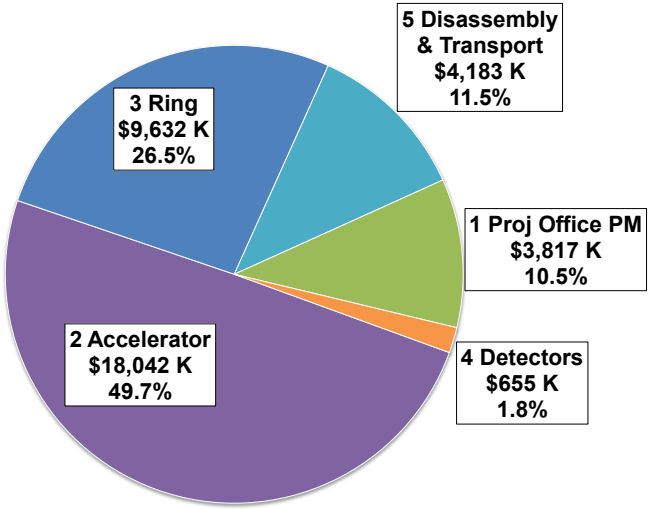
Storage Ring	Storage ring yoke pieces, pole pieces, and superconducting coils have been installed and are ready to be cooled and powered.	Storage ring yoke pieces, pole pieces, and superconducting coils have been cooled and powered to full 1.5T field.
Storage Ring Subsystems	Storage ring subsystems, including the electrostatic quadrupoles, pulsed electromagnetic kickers, and inflector, are ready to install.	Storage ring subsystems, including the electrostatic quadrupoles, pulsed electromagnetic kickers, and inflector, are installed and ready for commissioning with beam at nominal voltages and currents.
NMR Systems	Nuclear magnetic resonance (NMR) systems for monitoring magnetic field, including fixed probes, plunging probes, and NMR trolley, are ready to install.	Nuclear magnetic resonance (NMR) systems for monitoring magnetic field, including fixed probes, plunging probes, and NMR trolley, are installed and ready for commissioning with beam at nominal values.

- There will be another round of discussion on the KPPs for g-2 prior to the CD-2/3 approval that we anticipate in June/July
  - Defining KPPs is a balance of achieving requirements required to meet mission need, while not being so constrained that transitioning from project to operational goals is impeded

Project Cost

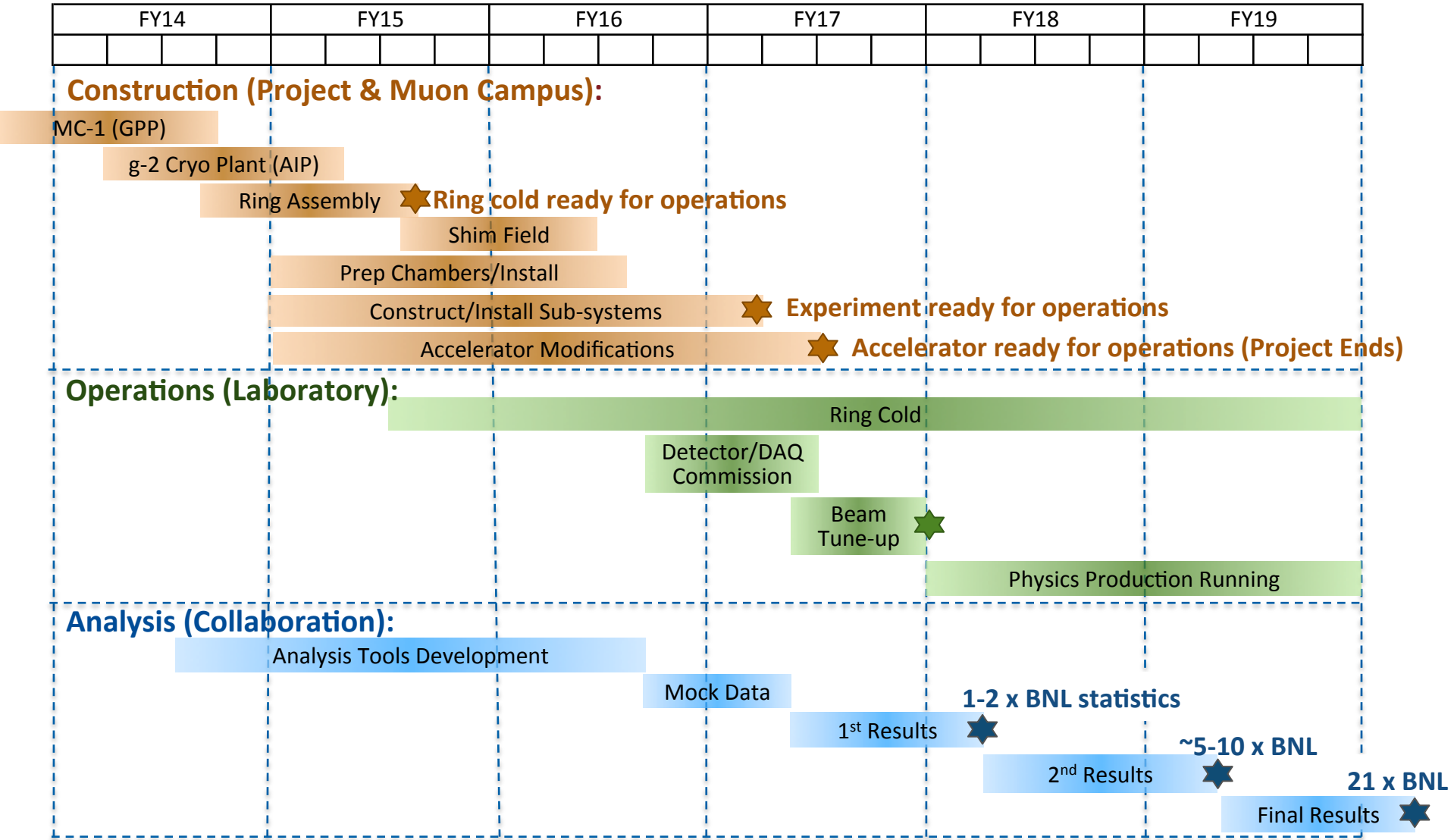
CD-2/3 project base (no contingency or risk) costs

DOE	Fermilab Labor	M&S	Non-FNAL Labor	Total
476 Muon g-2	Base ($K)	Base ($K)	Base ($K)	Base ($K)
1 Proj Office PM	2,288	781	747	3,817
2 Accelerator	10,350	7,692	0	18,042
3 Ring	4,319	3,988	1,326	9,632
4 Detectors	170	445	41	655
5 Disassembly & Transport	280	3,903	0	4,183
Grand Total	**17,407**	**16,809**	**2,114**	**36,329**



- Have been measuring performance against plan established in May 2014
  - Total estimate at completion now at $37.0M, $700k increase primarily from additional effort used in ring reassembly
  - $15.3M work completed, project is 41.5% complete
  - $9.4M remaining contingency, 43% of base cost to go

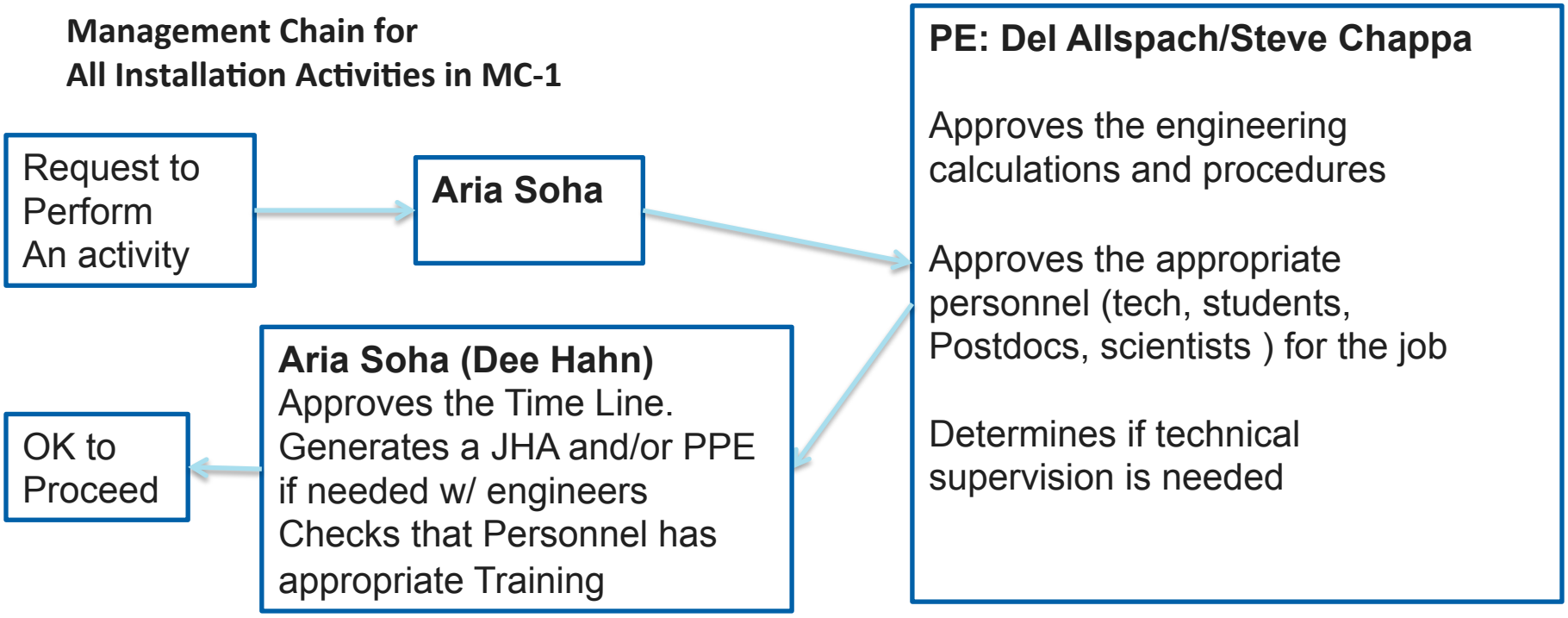
Project Schedule



ESH&Q

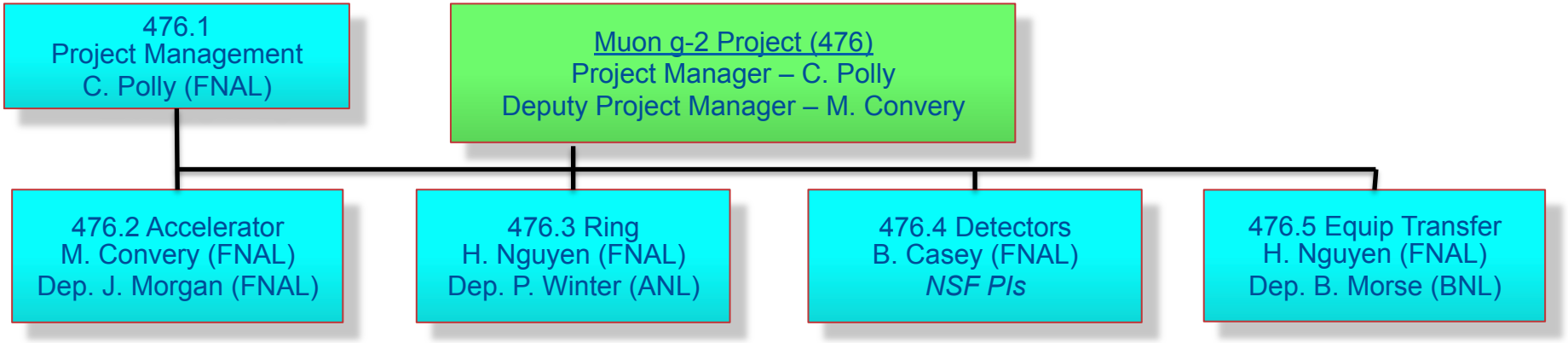
- Safety integrated into Lab management at all levels.
  - Project embedded in Lab's line Management
- Oversight by Lab ESH&Q organization as well as by Division & Section ES&H organizations
- Project ESH&Q coordinator – Araia Soha
  - Safety coordinator work in the experimental hall
- Integrated Safety Management Plan developed (GM2-docdb-1267)
- Hazard Analysis Report including evaluation and mitigation of safety risks developed and posted (GM2-docdb-1923)
- NEPA Categorical Exclusion
- ORCs and JHAs
- Quality Assurance Plan (GM2-docdb-1249)
- Custom QA/QC plan tailored to each L3 subsystem
- Extensive QA planning exercised for ring transport

Example from training provided to work managers



- If you are planning on visiting or doing work in MC-1, contact Aria to make sure you have appropriate hazard training
- Working regularly? Need to be on daily hazard e-mail distribution
- Check whiteboard posting in MC-1 where daily hazards are posted

Scientific Personnel Playing Major L2 Roles in Project

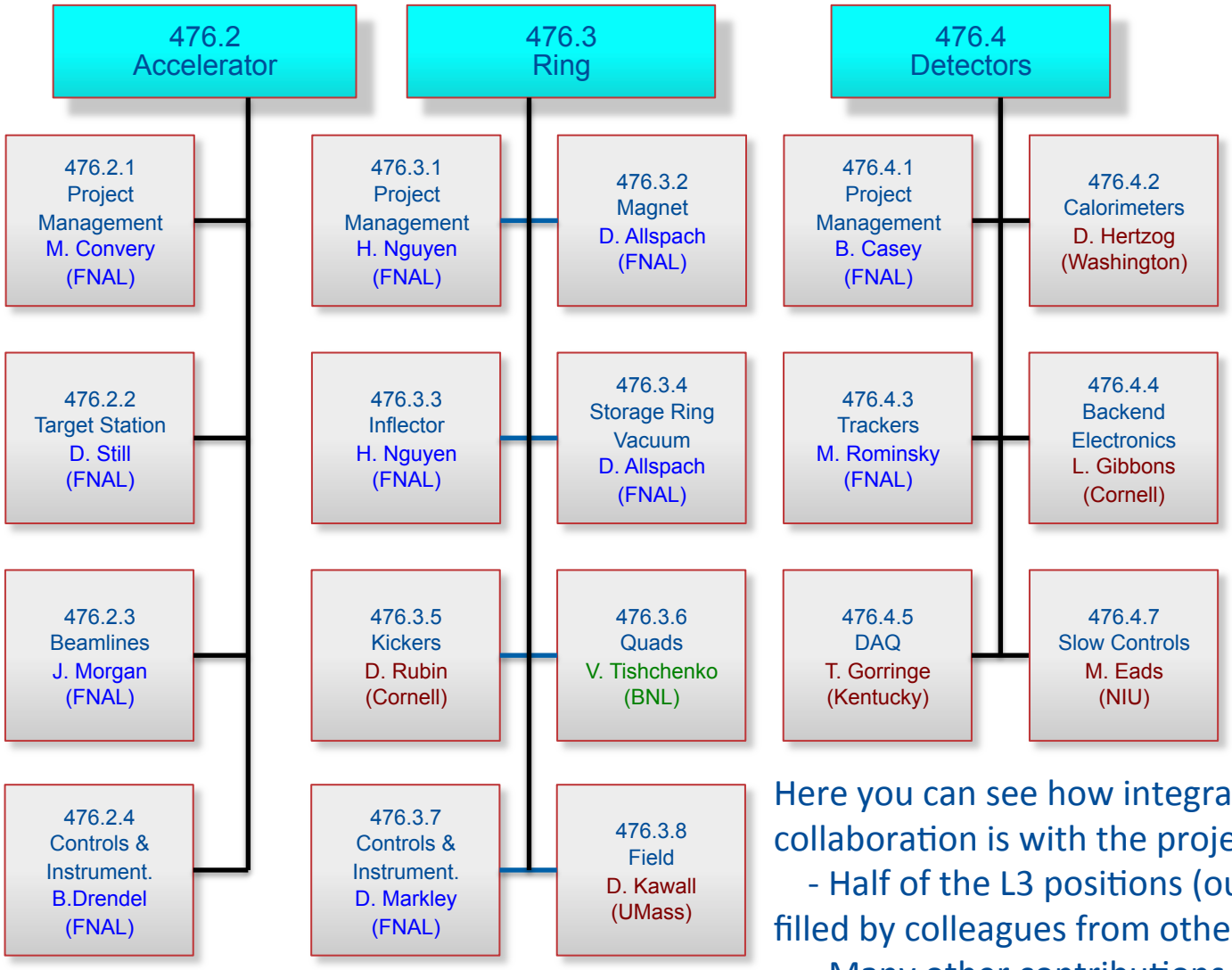


- Mary Convery
  - Dep project manager and L2 for accelerators
- Hogan Nguyen
  - L2 for Ring and Equipment Transfer
- Brendan Casey
  - L2 for Detectors and PI for Early Career
- Bill Morse (BNL)
  - Major role in coordinating equipment transfer from BNL side
- Peter Winter (ANL)
  - Deputy L2 manager with an emphasis on the magnetic field measurement

Navigating the DOE CD process, making informed design decisions to maximize the physics potential, motivating people to give 100% & overseeing construction with and eye towards the ultimate scientific success is an enormous responsibility.

I simply can't say enough about how much every one of these scientists and our NSF PIs pour everything they have into it!

Project roles at L3



L3 managers also have major responsibilities

Here you can see how integrated the scientific collaboration is with the project

- Half of the L3 positions (outside of accelerator) are filled by colleagues from other universities and labs
- Many other contributions become visible at L4

Project/collaboration interaction

- Project team and PIs from scientific collaboration are very integrated
- Many meeting to facilitate and reach consensus on decisions
- How do we ensure everyone's interests are properly represented?
  - Prior to CD-2
    - The scientific collaboration as a whole were the drivers in developing conceptual and technical design reports that laid out the baseline plan
    - Everyone had ample opportunity to contribute ideas, review the documents, and reach consensus
    - Sometimes optional scope was still in debate -> enters risk registry so that the potential cost and schedule impact was acknowledged
  - Now until the project is complete
    - The 'baseline' has been established in the TDR
    - Any changes from the baseline must first go before the change board who make a recommendation to the project manager
    - Change board currently consists of PM, deputy PM, L2 managers and spokespeople (who are advised by the collaboration IB)
    - If broad consensus cannot be achieved then a technical review team can be assembled and charged by project to provide input

Conclusion

- Muon g-2 is in a very exciting phase…construction in full swing and the next experiment on deck to take data at FNAL
- In general, the project is in good shape with respect to cost and schedule
- DOE and the laboratory have been very supportive
- The personnel involved with the project are making enormous contributions
- The project and scientific collaborations are fully integrated with a common goal of building the best experiment possible

Thank You!