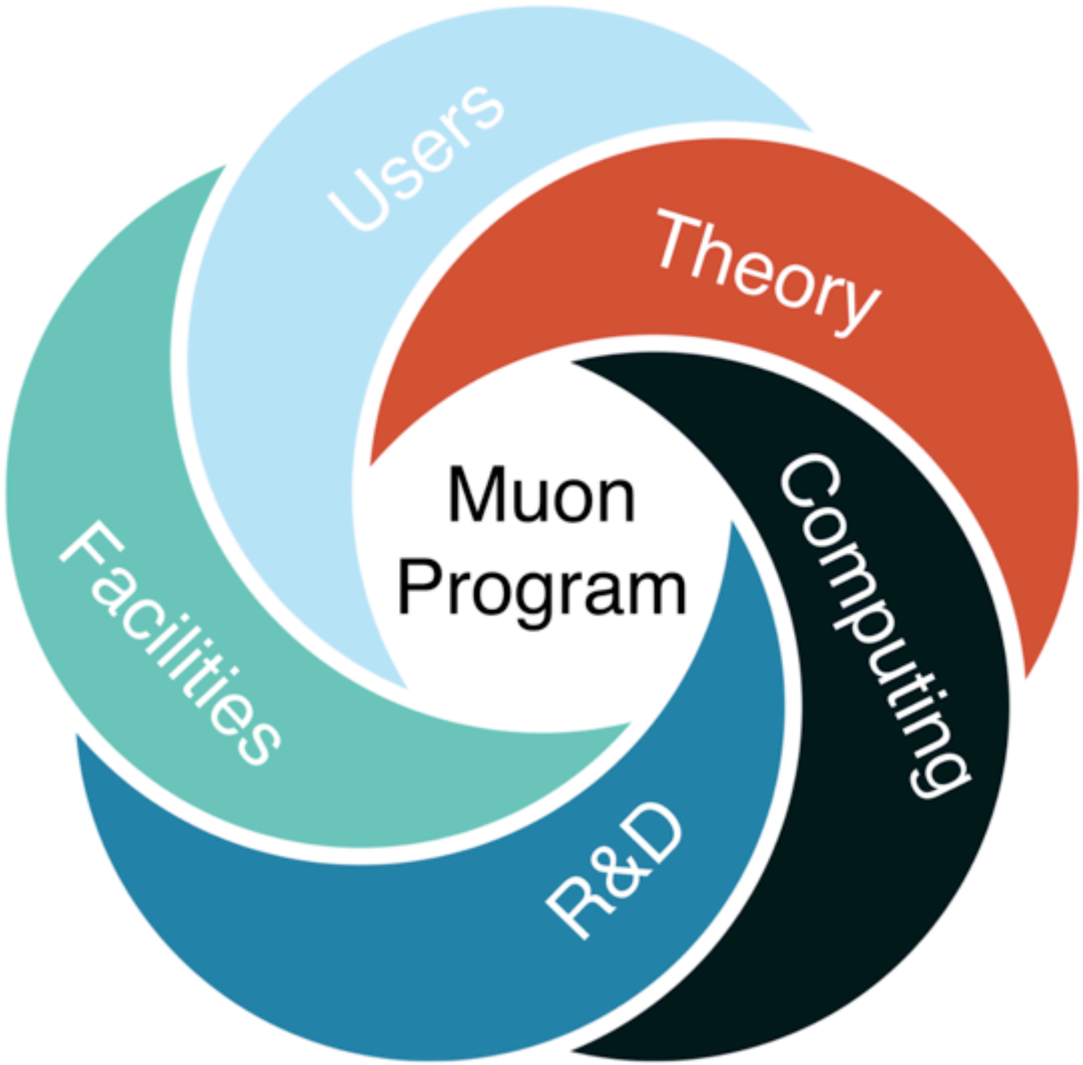
Fermilab
Managed by Fermi Research Alliance, LLC for the U.S. Department of Energy Office of Science

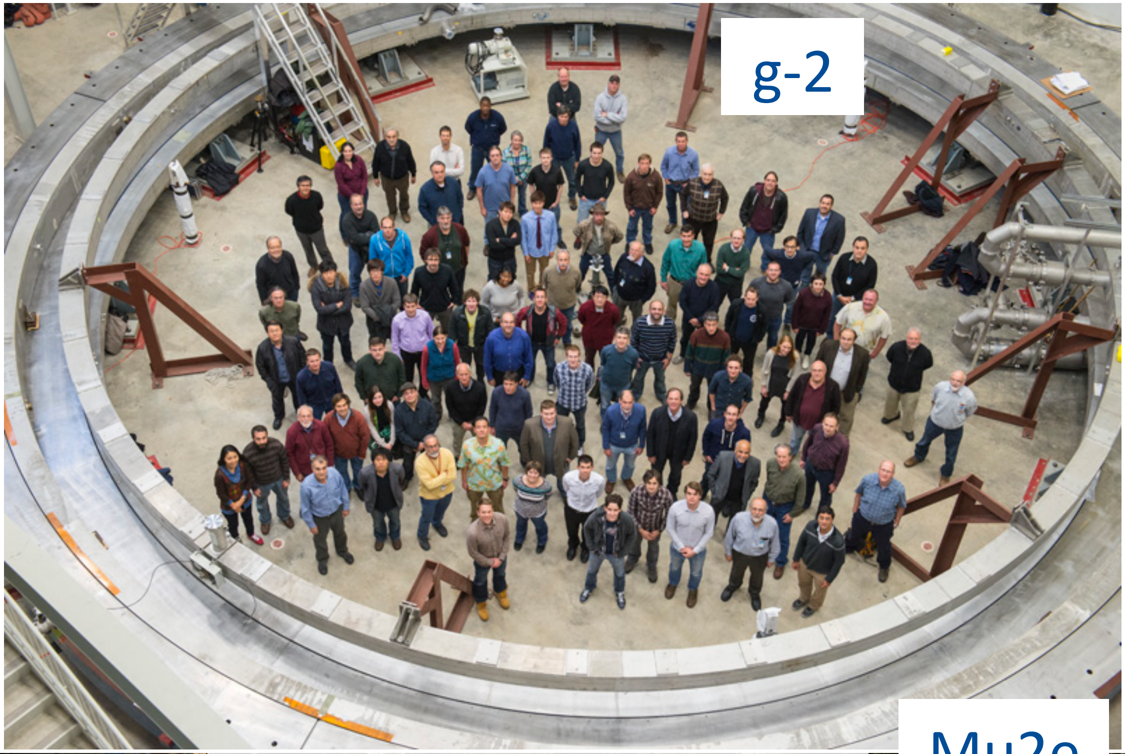
Muon Wrap Up

Brendan Casey and Doug Glenzinski
Institutional Review
12 February 2015

Muon Cross-Cut



Muon cross-cut: Users



50 institutions in 8 countries

4 US National Labs

Over 300 users. ~50 users retained from the Tevatron program

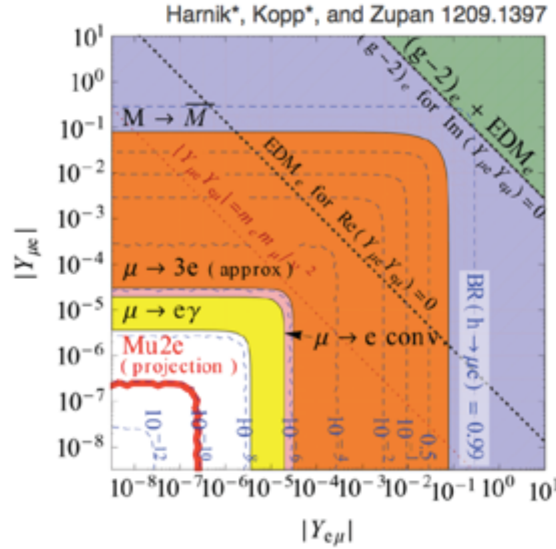
Muon cross-cut: Theory

Strong participation from Fermilab theorists

The lab enables the national lattice program

Engagement of the university community

LFV Yukawas



B(H->μe~10^{-10})

Lattice hardware

The Muon $(g-2)$ Theory Value: Present and Future

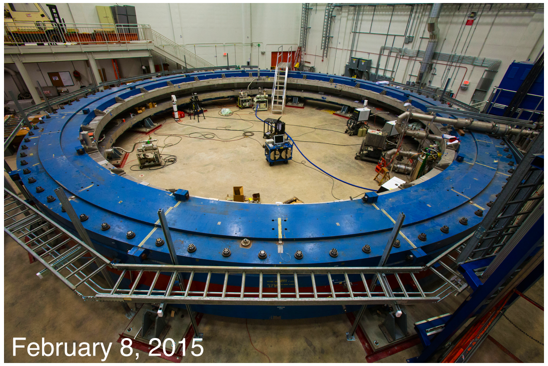
Thomas Blum[1], Achim Denig[2], Ivan Logashenko[3], Eduardo de Rafael[4], B. Lee Roberts[5], Thomas Teubner[6], Graziano Venanzoni[7]

Error	[20]	[21]	Future
$\delta a_\mu^{\rm SM}$	49	50	35
$\delta a_\mu^{\rm HLO}$	42	43	26
$\delta a_\mu^{\rm HLbL}$	26	26	25
$\delta(a_\mu^{\rm EXP} - a_\mu^{\rm SM})$	80	80	40

Updates to g-2 theory

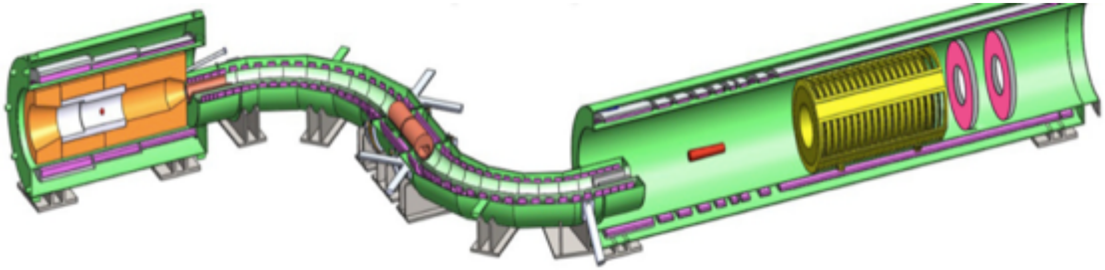
Fermilab

Muon cross-cut: Facilities



~$100M in savings by creating an integrated program

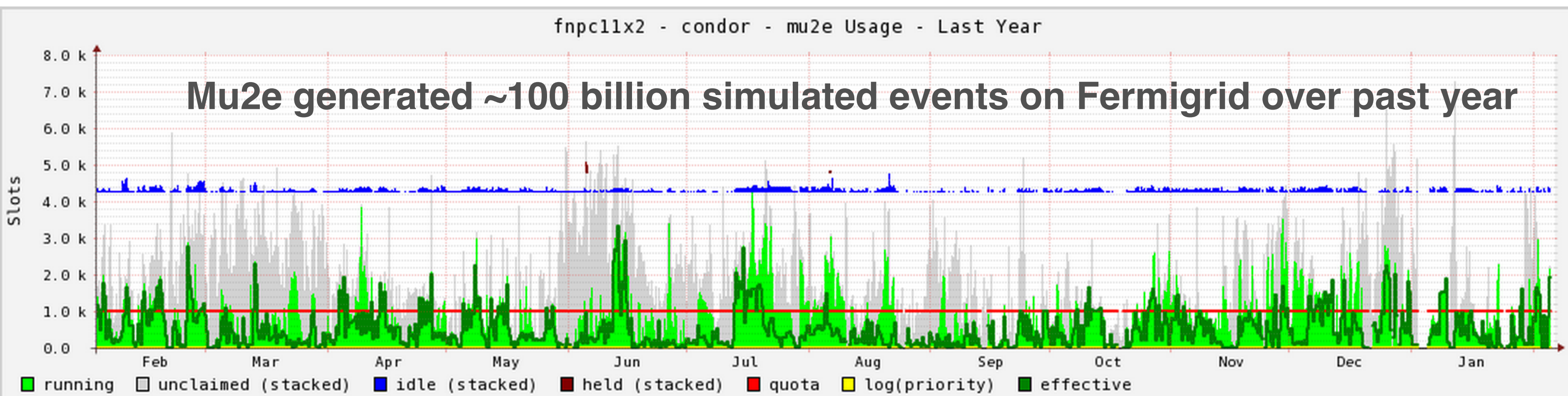
Beautiful, world-class facilities to serve the community well into next decade and beyond



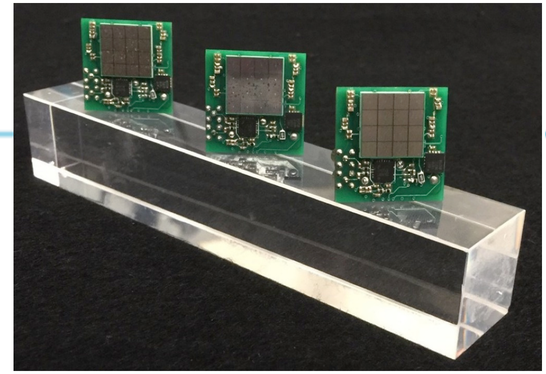
Muon cross-cut: Computing

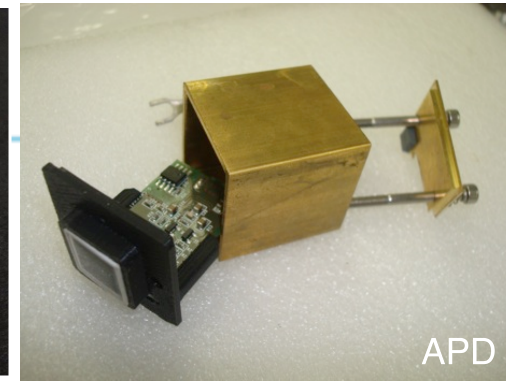
Clear recognition by the lab that this is vital to our mission and a major concern of our users.

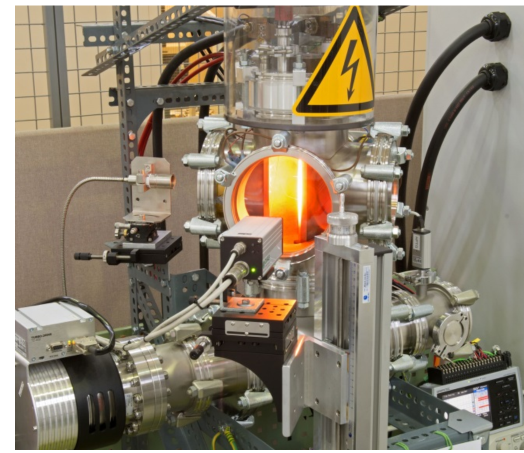
Full engagement of collaborations and leveraging of available resources.



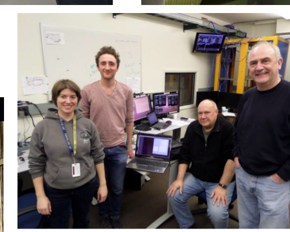
Muon cross-cut: R&D







Leading contributions to:
EM calorimetry, photo-detectors, in-vacuo technology, GPU-based DAQ, high power targetry, beam monitoring, He^3 magnetometry.



Making use of facilities at Fermilab, Frascati, SLAC, PSI, and RAL

Charge questions

Question 1

- The quality and significance of the lab's recent scientific and technical accomplishments
- The merit, feasibility, and projected impact of the future planned physics program
- P5 alignment

Lyon, Ray, Polly, Convery, Kiburg, Knoepfel

Question 1

- The quality and significance of the lab's recent scientific and technical accomplishments

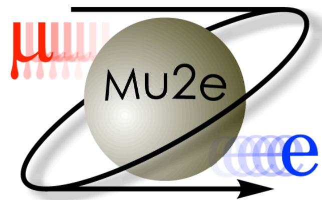
Muon $g - 2$ Technical Design Report

July, 2014
Fermi National Accelerator Laboratory
Batavia, IL 60510
www.fnal.gov
Managed by
Fermi Research Alliance, FRA
For the United States Department of Energy under
Contract No. DE-AC02-07-CH-11359

Contacts: C. Polly – Project Manager (polly@fnal.gov)
K.W. Merritt – Deputy Project Manager (wyatt@fnal.gov)
D. Hertzog – Co-Spokesperson (hertzog@uw.edu)
B. L. Roberts – Co-Spokesperson (roberts@bu.edu)

U.S. DEPARTMENT OF ENERGY | Office of Science

Fermilab



Mu2e Technical Design Report

October 2014

Fermi National Accelerator Laboratory
Batavia, IL 60510
www.fnal.gov

Managed by
Fermi Research Alliance, FRA
For the United States Department of Energy under
Contract No. DE-AC02-07-CH-11359

U.S. DEPARTMENT OF ENERGY | Office of Science

INFN

Fermilab

CD2/3 reviews completed

Muon campus 50% complete

Mu2e ready for first solenoid purchases

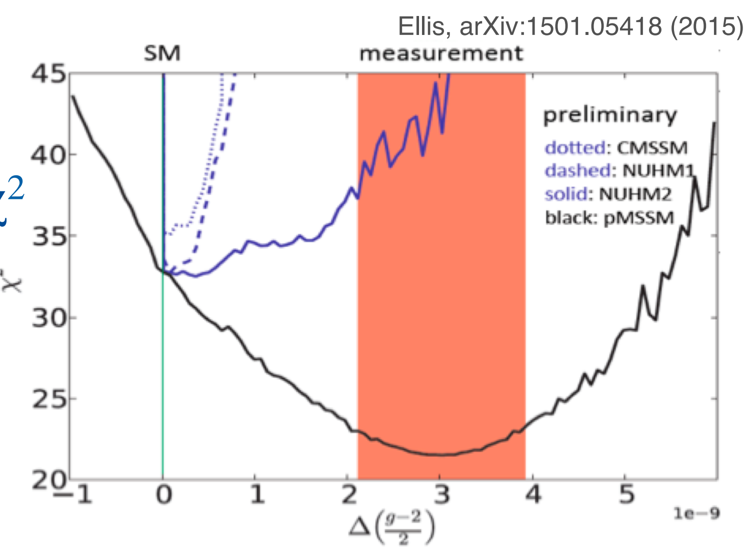
g-2 ring expected to be cold and powered before summer

Lyon, Kiburg, Knoepfel

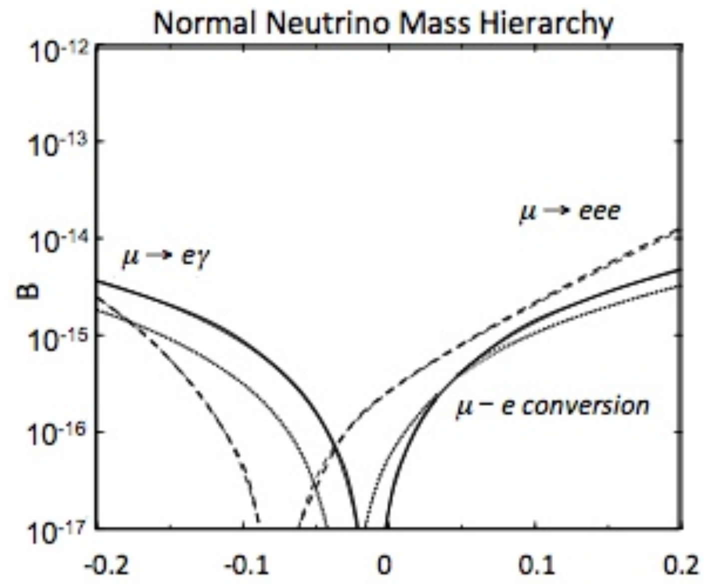
Question 1

- The merit, feasibility, and projected impact of the future planed physics program
  - We will do the definitive muon g-2 experiment and the most sensitive charged lepton violation experiment
  - Large overlap with physics at the LHC and LBNF
  - Unique capabilities beyond LHC and LBNF

SUSY χ^2 to LHC Run I



g-2



R(μe)

Θ_{13} x cosδ

Lyon

Question 1

- P5 alignment

Recommendation 22: Complete the Mu2e and muon g-2 projects.

Project/Activity	Scenarios: Scenario A	Scenario B	Scenario C	Science Drivers: Higgs	Neutrinos	Dark Matter	Cosm. Accel.	The Unknown	Technique (Frontier)
Large Projects									
Muon program: Mu2e, Muon g-2	Y, Mu2e small reprofile needed	Y	Y					✓	I
HL-LHC	Y	Y	Y	✓		✓		✓	E
LBNF + PIP-II	Y, LBNF components delayed relative to Scenario B.	Y	Y, enhanced		✓			✓	I,C
ILC	R&D only	R&D, possibly small hardware contributions. See text.	Y	✓		✓		✓	E

Question 2

- The effectiveness and efficiency of facility operations and the planning for future facilities to support the research program

- The appropriateness of proposed performance metrics in terms of being realistic and maximizing the scientific productivity of the facility.

Convery. Ray, Polly

Question 2

- The effectiveness and efficiency of facility operations and the planning for future facilities to support the research program

Milestone Name	Responsibility	Impacts	Forecast	Needed by	Actual
MC-1 Bldg Beneficial Occupancy for Cryo	MC-1 Building GPP	Cryo AIP	1/8/14	as soon as possible	1/8/2014
MC-1 Bldg Beneficial Occupancy for g-2 Ring	MC-1 Building GPP	g-2	4/10/14	as soon as possible	4/10/2014
End of Circulating Beam Studies	g-2, Mu2e	g-2, Mu2e, Delivery Ring AIP	4/25/14	6/30/14	4/25/2014
MC-1 Cryo Room Controls Available	MC-1 Building GPP	Cryo AIP	9/22/14	as soon as possible	6/6/2014
Cryo Compressor Cooling Established	MC Infrastructure GPP	Cryo AIP	9/30/14	10/31/14	8/15/2014
Cryo g-2 acceptance tests complete	Cryo AIP	lower-level milestone for g-2	10/24/14	as soon as possible	10/2/2014
Cryo Ready to Cool g-2	Cryo AIP	g-2	3/15/15	as soon as possible	11/30/2014
D30 Straight Section Ready for New Installation	g-2	Delivery Ring AIP	2/5/15	5/17/16	1/31/2015
MI-52 Bldg Extension Beneficial Occupancy	MC Infrastructure GPP	Beam Transport AIP	6/30/15	9/30/15	
Beamline Enclosure Beneficial Occupancy	Beamline Enclosure GPP	g-2	2/1/16	2/15/16	
Beam Transport Complete	Beam Transport AIP	g-2, Mu2e	2/1/16	3/31/17	
Recycler RF Complete	Recycler RF AIP	g-2, Mu2e	9/30/16	3/31/17	
Delivery Ring Complete	Delivery Ring AIP	g-2, Mu2e	9/30/16	3/31/17	
Shield Wall Installation	g-2	Mu2e	1/5/17	before g-2 running	
Cryo: Mu2e Distribution Box Cold	Cryo AIP	Mu2e	7/15/17	9/15/17	

Muon campus milestones

Question 2

- The appropriateness of proposed performance metrics in terms of being realistic and maximizing the scientific productivity of the facility.

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.

Main stakeholders are DOE, Collaboration, and Lab. Everyone involved in making the KPPs and everyone has the same goal of getting to physics results ASAP

Question 3

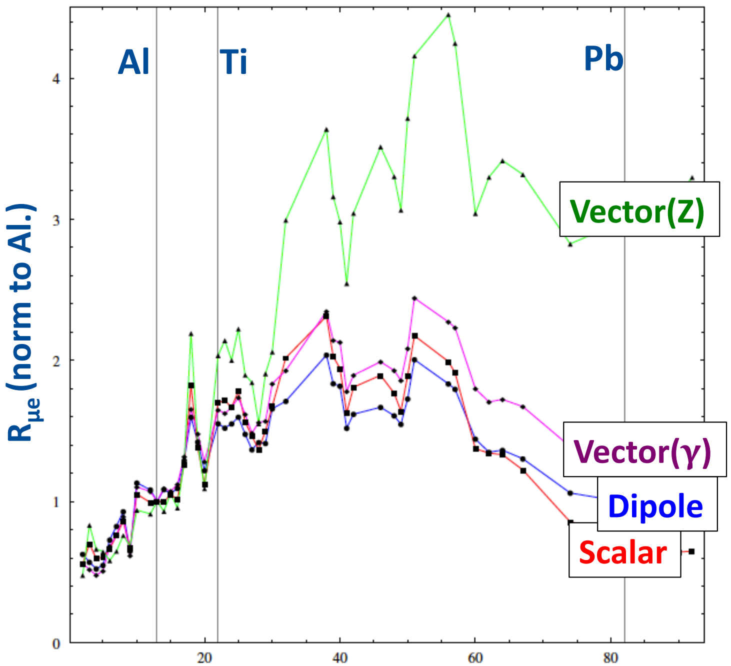
- The effectiveness of the lab management in
  - Strategic planning
  - Core competencies
  - Implementing prioritized and optimized plan
- Promoting and implementing a safe work environment

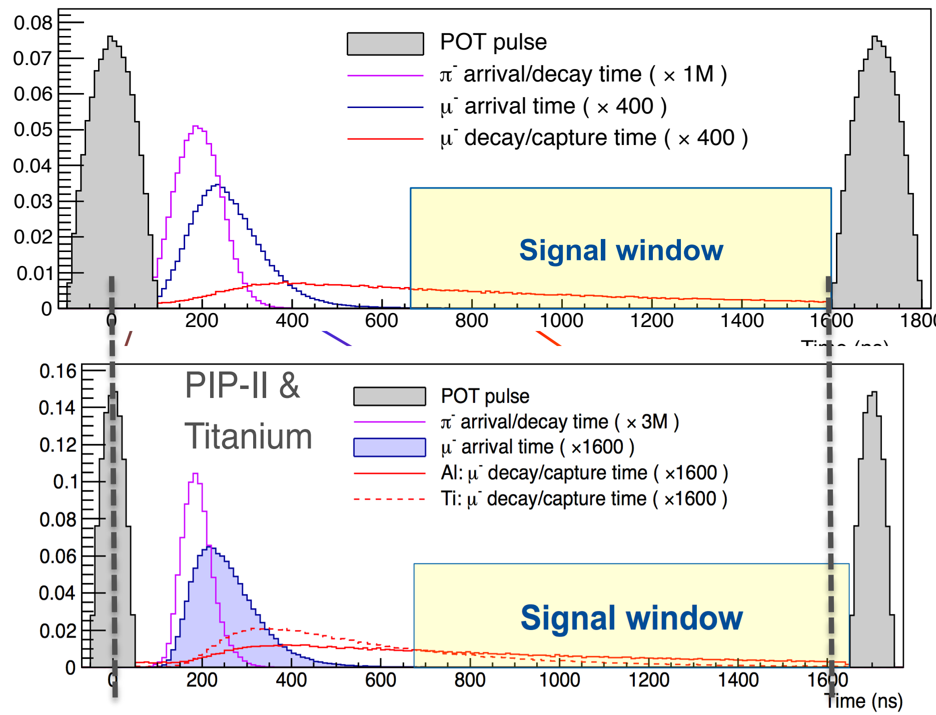
Question 3

- The effectiveness of the lab management in
  - Strategic planning
  - Core competencies
  - Implementing prioritized and optimized plan

Clear upgrade strategy worked out for Mu2e including physics case, planned accelerator upgrades and well defined branch points

Cirigliano, et al PRD **80**, 013002 (2009)





2/12/15

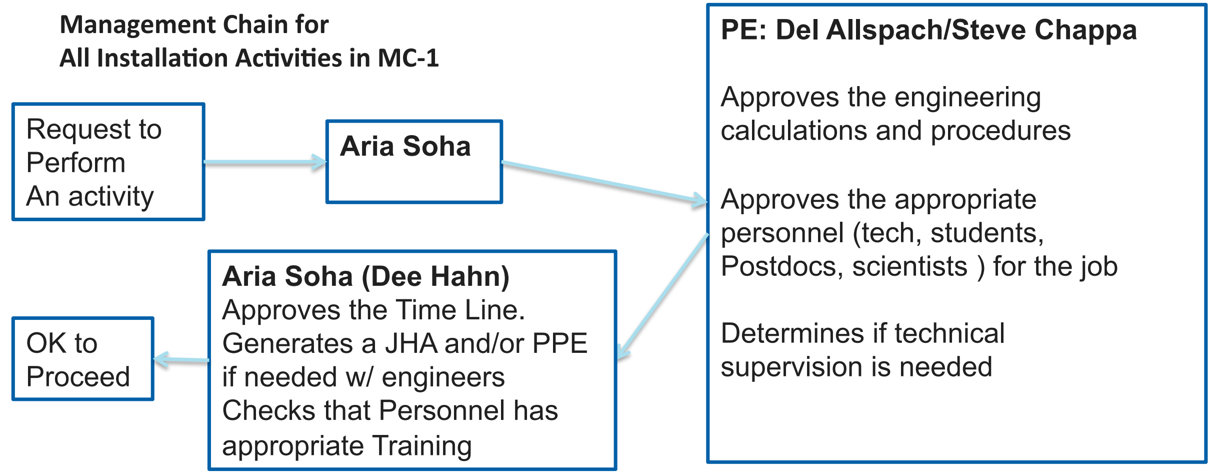
Ray, Polly, Convery

Question 3

- Promoting and implementing a safe work environment

Absolute Highest Priority

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

Question 4

- The effectiveness of the development and oversight of projects
- Integration of universities and other national labs in projects

Question 4

Ray, Polly, Convery, Lindgren, James

- The effectiveness of the development and oversight of projects

Office of the CPO
Mike Lindgren
Chief Project Officer

Office of Project
Support Services
Marc Kaducak

Working hard to improve tools for project development and optimizing resource allocation across the lab

Both muon projects should be baselined by summer

Muon campus, projects on schedule and on budget

Question 4

Ray, Polly, Convery

- Integration of universities and other national labs in projects

Muon g-2:
58% of project management positions held by non-Fermilab collaborators.

Almost all detector construction occurring at universities

Major beamline components being constructed at other labs
- Cornell: Kicker
- BNL: electrostatic quads
- ANL: trolley, MRI test facility

Mu2e:
Most project management positions associated with the detectors held by non-Fermilab collaborators

Almost all detector construction occurring at universities

Major design and software development efforts at other labs
- LBNL: Track reconstruction
- BNL: CSC CRV test stand
- ANL: Tracker assembly fixtures, B field mapping units

Question 5

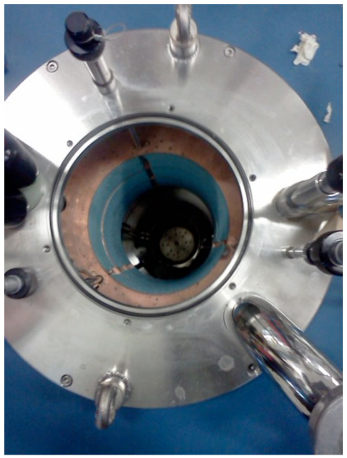
- The leadership, creativity, and productivity of the lab's scientific and technical staff

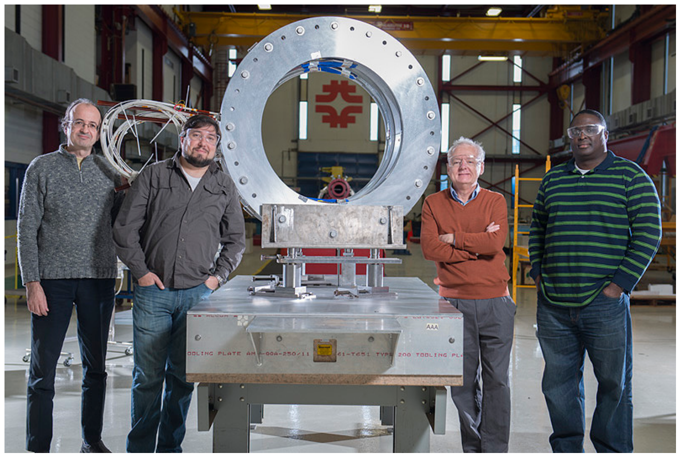
Lyon, Convery, Ray, Polly

Question 5

Demonstrating that detectors can be built using the lowest mass straws in vacuum

- Technical

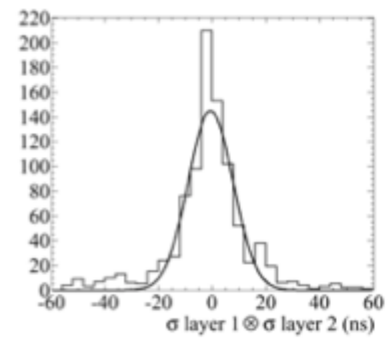




TD

shi

Cable development for Mu2e and shield development for g-2

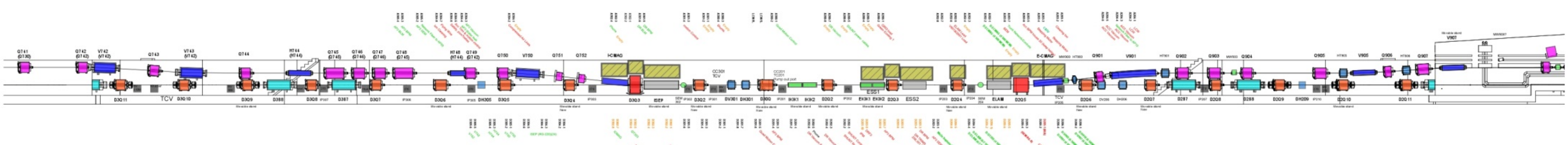


8ns res in data

9ns in GARFIELD after applying effective threshold from beam

Corresponds to 270 μm resolution

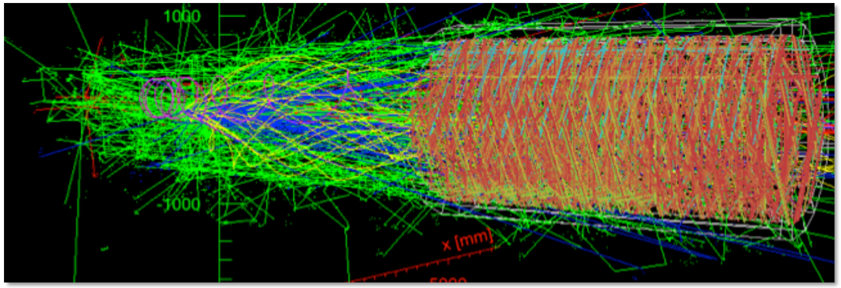
Highly constrained beamline design



Lyon, Kiburg, Knoepfel

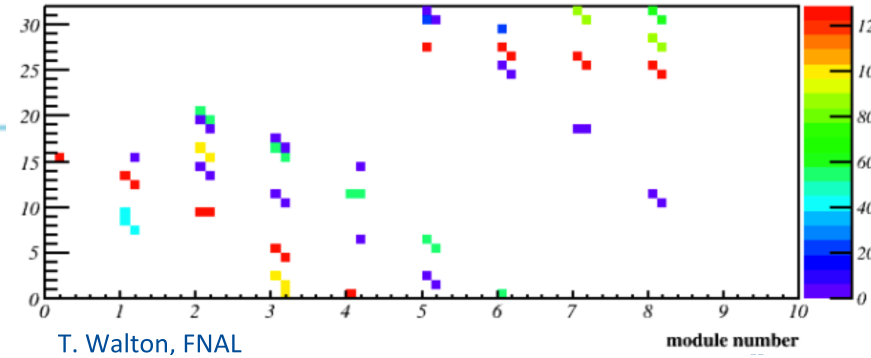
Question 5

- Scientific



Mu2e full background simulation and systematic evaluation

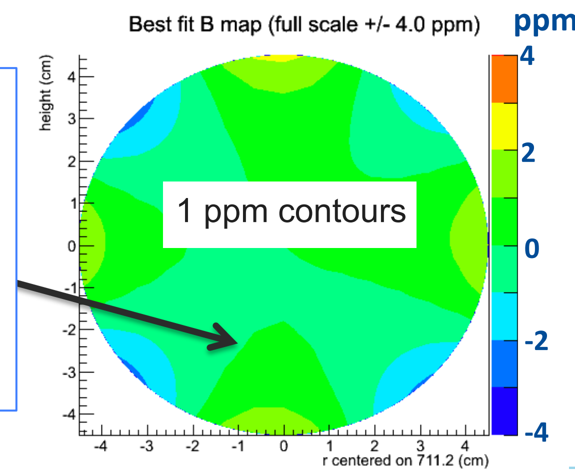
Effect	Uncertainty in DIO background yield	Uncertainty in CE single-event-sensitivity ($\times 10^{-17}$)
MC Statistics	±0.02	±0.07
Theoretical Uncertainty	±0.04	-
Tracker Acceptance	±0.002	±0.03
Reconstruction Efficiency	±0.01	±0.15
Momentum Scale	+0.09, -0.06	±0.07
μ-bunch Intensity Variation	±0.007	±0.1
Beam Flash Uncertainty	±0.011	±0.17
μ-capture Proton Uncertainty	±0.01	±0.016
μ-capture Neutron Uncertainty	±0.006	±0.093
μ-capture Photon Uncertainty	±0.002	±0.028
Out-Of-Target μ Stops	±0.004	±0.055
Degraded Tracker	-0.013	+0.191
Total (in quadrature)	+0.10, -0.08	+0.35, -0.29



T. Walton, FNAL

Tracking code for g-2

Preparations for measuring the proton precession frequency



Leading authors of over a dozen Tevatron legacy publications in the last 3 years

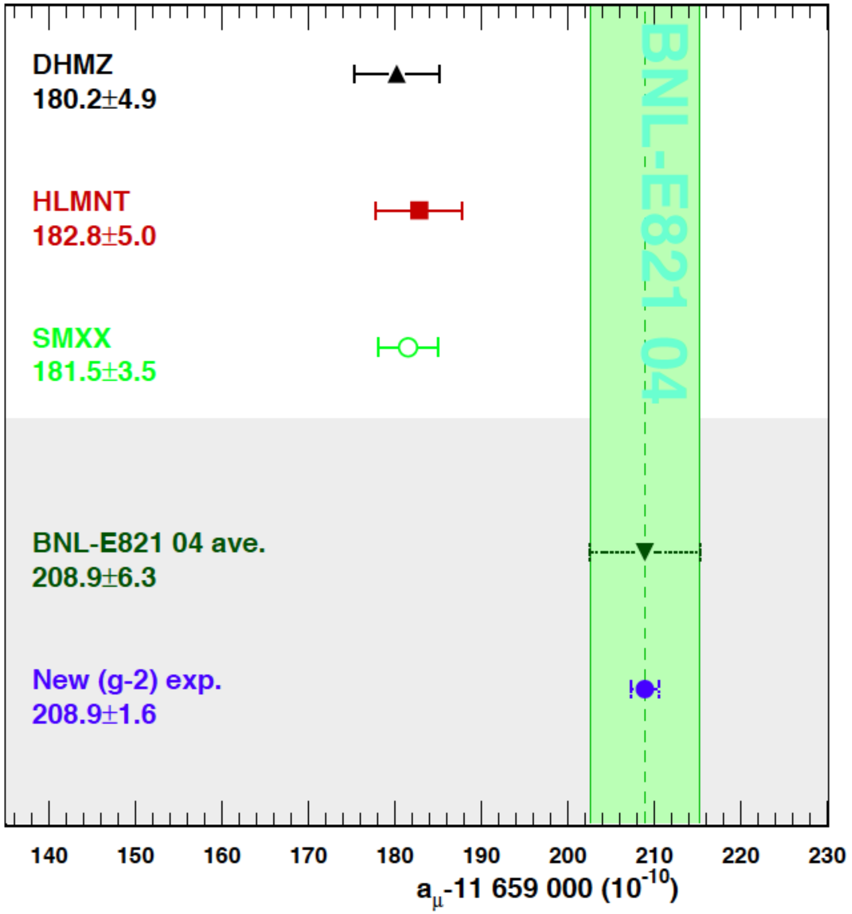
Question 6

- The quality and appropriateness of the lab's interactions with, and nurturing of its scientific community
-

Lyon, Kiburg, Roser, Geer + closed and extra sessions

Question 6

- The quality and appropriateness of the lab's interactions with, and nurturing of its scientific community
  - Snowmass leadership and participation
  - Enabling analysis, grid, ART, workshops, schools
  - IF/URA Fellowships
  - Improving the way we communicate changes in proton planning
  - Office space: Frank discussions
  - Trying to move forward together with our university partners in a mutually beneficial way in a time of constrained budgets and changing norms.



The Muon $(g-2)$ Theory Value: Present and Future

Thomas Blum[1], Achim Denig[2], Ivan Logashenko[3], Eduardo de Rafael[4], B. Lee Roberts[5], Thomas Teubner[6], Graziano Venanzoni[7]

More comfortable room for short term visitors

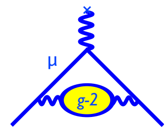
More open and optimized space for long term visitors

More administrator help

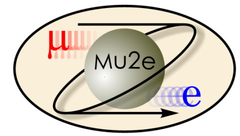
Still leaves us a factor of 2 below our current needs but we are working on that too.

Summary

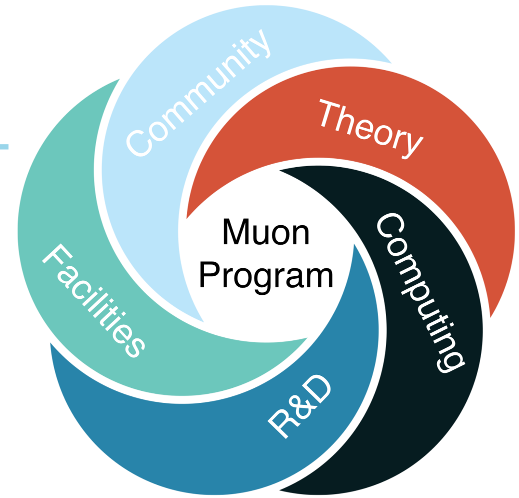
The Muon program…



+



+



brings together all parts of the lab

and collaborators from institutions world-wide

to make a program more than the sum of its parts

to do precision physics that may lead

to vital discoveries beyond the Standard Model