



Fermilab Intensity Program

Nigel S. Lockyer

HEPAP Meeting

2 December 2016

Overview

- Intensity frontier
 - LBNF/DUNE, NOvA, MINERvA, SBN, LArIAT, Muon g-2, Mu2e
- Computing
- University
 - LHC and Neutrino physics centers, Distinguished Scholars
- Questions

Intensity frontier

Initial Far Site Construction for LBNF: APPROVED



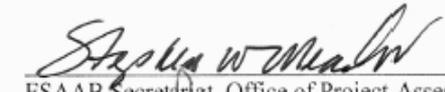
CD-3a Milestone

- On 9/1/16, DOE Under Sec'ty for Science and Energy **approved** the CD-3a milestone
- Paves the way to start ~\$300M in construction at far site in FY17
- This approval:
 - Signifies DOE's **strong commitment** to move the project forward,
 - Provides impetus to solidify international partnerships, and
 - Positions DUNE to rapidly pursue its science objectives.

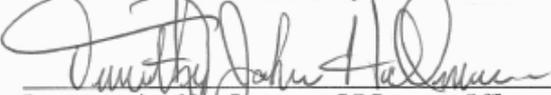
Critical Decision 3a, Approve Initial Far Site Construction for the LBNF/DUNE Project

Recommendations:

The undersigned "Do Recommend" (Yes) or "Do Not Recommend" (No) approval of Critical Decision 3a, Approve Initial Far Site Construction for the LBNF/DUNE Project at the SURF site as noted below.



ESAAB Secretariat, Office of Project Assessment 9/1/16 Yes No
Date



Representative, Non-Proponent SC Program Office 9/1/2016 Yes No
Date

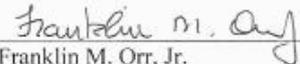
Concurrence:



C. A. Murray 9/1/16 Yes No
Director, Office of Science Date

Approval:

Based on the information presented in this document and at the ESAAB review, I approve Critical Decision-3a, Approve Initial Far Site Construction for the LBNF/DUNE Project.



Franklin M. Orr, Jr. 9/1/16
Under Secretary for Science and Energy Date

Far site: LBNF phases of work

1. Sanford Lab Reliability Projects

FY16 – 18

- Ross shaft rehab
- Hoist motor rebuilds, more...

2. Pre-Excavation

FY17 - 18

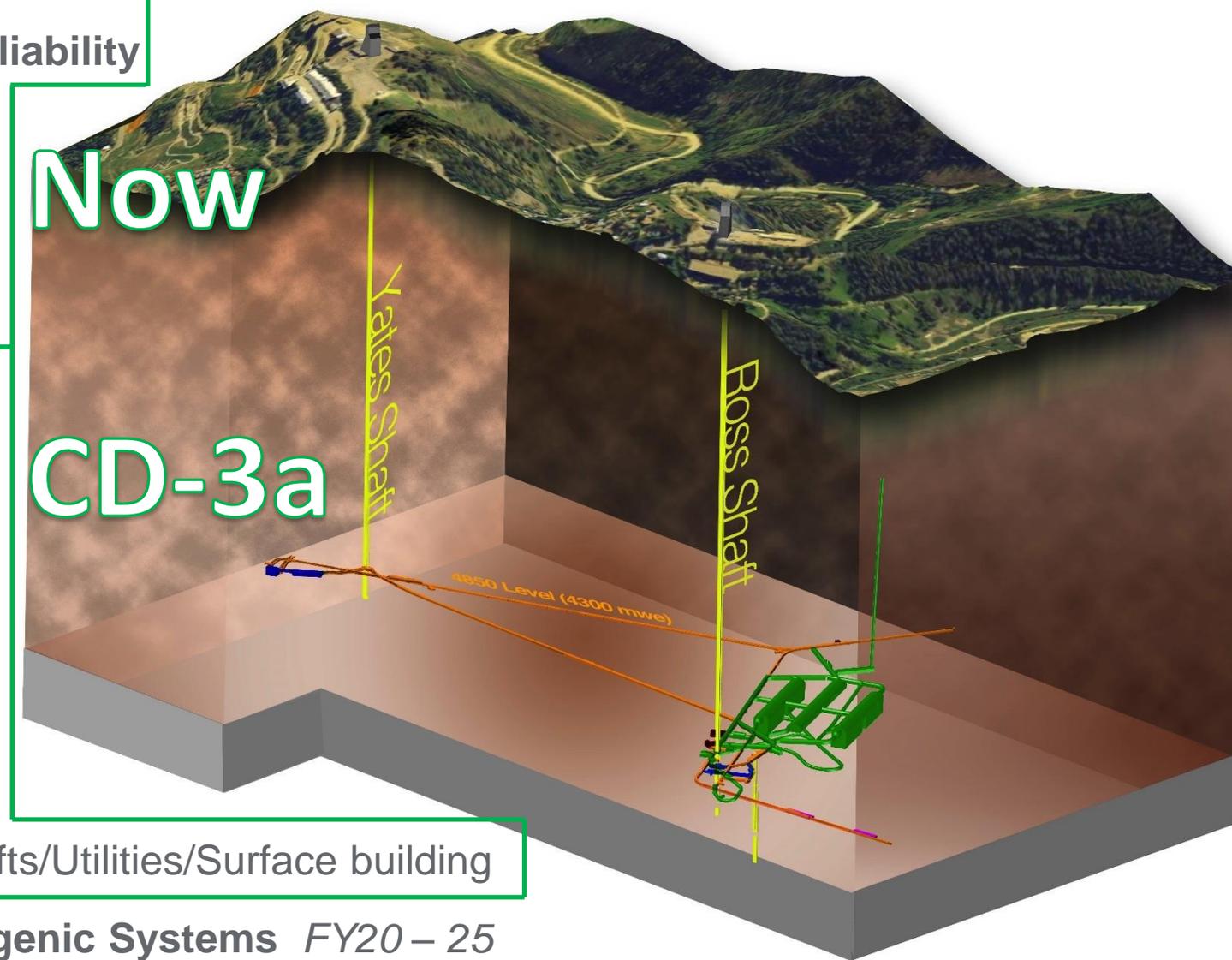
- Rock disposal systems
- Ross headframe upgrade, more...

3. Excavation/Construction

FY18 – 22

- Brow/Caverns/Drifts/Utilities/Surface building

4. Cryostats/Cryogenic Systems *FY20 – 25*



CM/GC: Actions since last HEPAP meeting



Pre-proposal conference – July 19th 2016

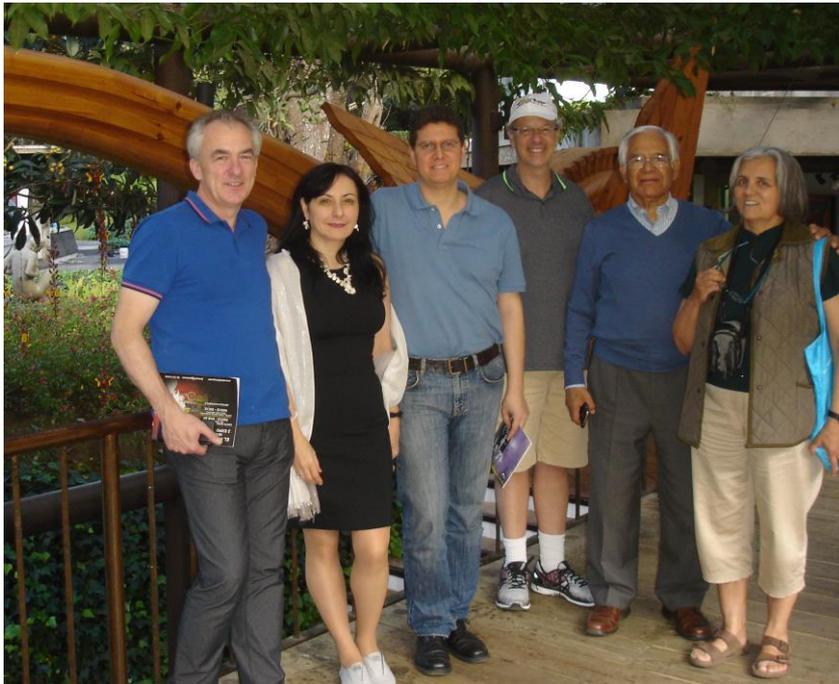
- ✓ CM/GC contract (construction manager/general contractor) has been advertised for potential bidders – 28 Jun 2016
- ✓ Pre-proposal conference held in South Dakota in July 2016
- ✓ Over 50 contractor representatives participated in conference; all representing well known and capable firms.
- ✓ Proposals currently due Dec 21, 2016

Fermilab and Latin America: A long-standing partnership gets even stronger



Latin American Neutrino Physicist meeting at Fermilab, April 2016

Fermilab and Latin America: A long-standing partnership gets even stronger



Mark Thomson and Marcela Carena at
SILFAE 2016, Guatemala, Nov 14-18



Marcela Carena with President of Cuban
Physical Society and Director of CEADEN,
Havana, July

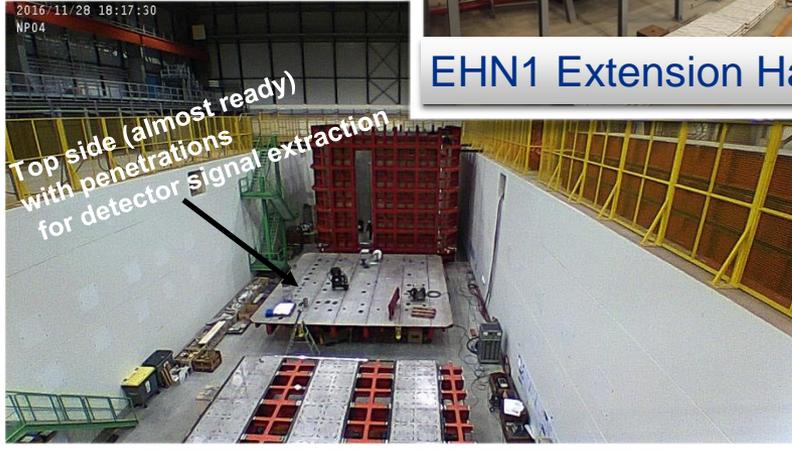
Hot topics for January collaboration meeting

- Co-spokesperson Election
 - Nomination/Selection of candidates for co-spokesperson election
 - Newly elected co-spokesperson in place by March
- Construction of ProtoDUNE prototypes at CERN
 - Already have strong teams in place to execute project
 - Now complete definition of downstream computing/analysis needs
- Formation of Far Detector Consortia
 - Initiate process for transition to “international consortia of institutions” responsible for elements of the far detector construction
- Put in place plans for preparing DUNE TDRs
 - Far Detector (single- and dual-phase), near detector, physics
- DUNE strategy update
 - Detailed definition of milestones, decision points, alternatives leading up to CD-2/3B.

Good Progress on ProtoDUNEs



EHN1 Extension Hall at CERN



Photos of ProtoDUNE cryostat external support under construction at CERN

Impressive progress...
many thanks to Marzio Nessi



- ProtoDUNEs under construction at the CERN Neutrino Platform
- Two prototype detectors:
 - *Single Phase*
 - *Double Phase*
- Both prototype teams growing with international collaborators
- Will take data using CERN test beam in 2018, prior to LHC long shutdown

MicroBooNE

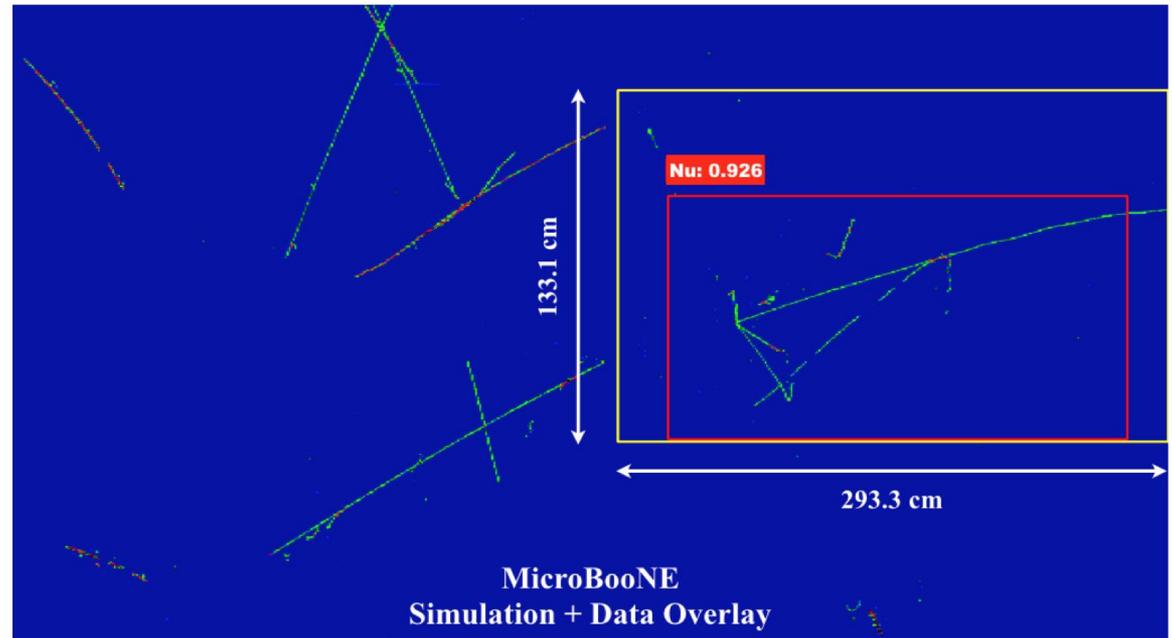
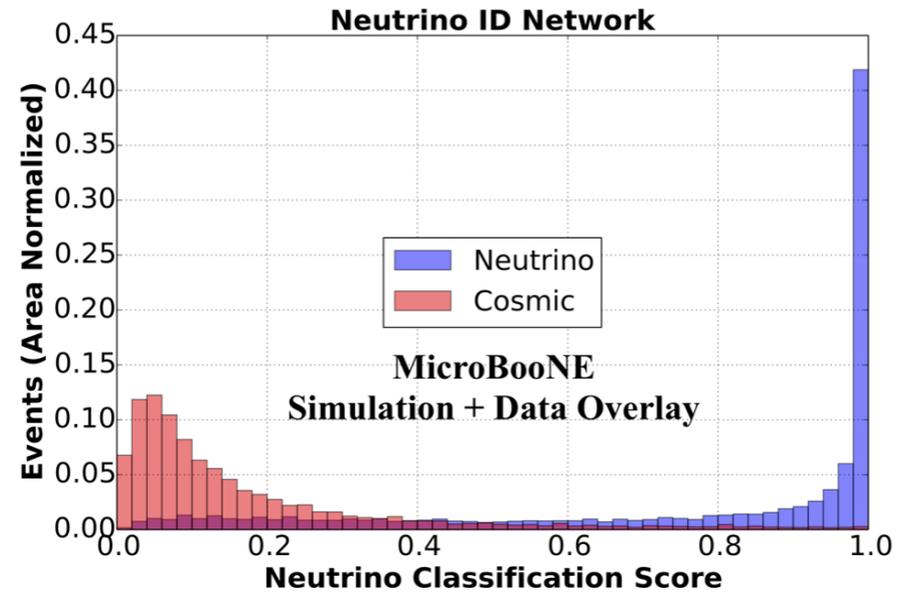
- **MicroBooNE had a busy shutdown**
 - Got a lot of work done. Completed multiple detector upgrades.
 - Ready for early startup. Started taking BNB a month early and collected 0.4×10^{20} POT thanks to the new interlock gates!
- **Installed new \$1M cosmic ray tagger from University of Bern, Switzerland**
 - Thanks to help from ND & PPD over the summer shutdown!
 - Crucial for measuring (large) cosmic backgrounds from surface operation.



MicroBooNE

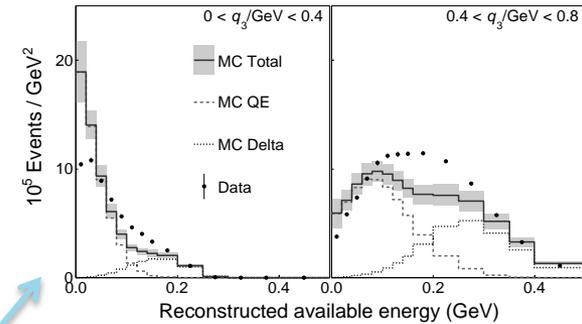
- MicroBooNE's produced first paper!

R. Acciarri et al.,
“Convolutional Neural Networks Applied to Neutrino Events in a Liquid Argon TPC”,
arXiv:1611.05531,
submitted to JINST

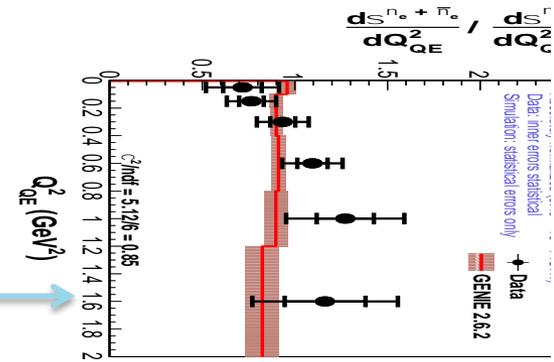


MINER ν A physics

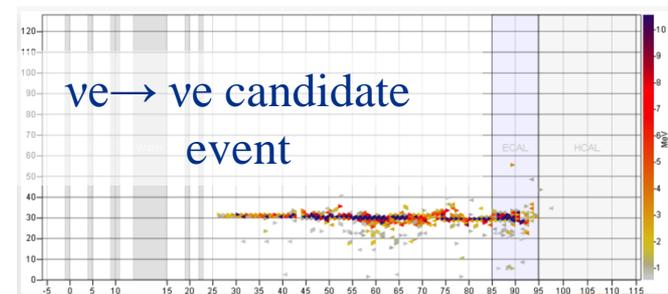
- Goal: Study ν interactions in exquisite detail
 - To help oscillation experiments get best measurement of neutrino energy, and predict signals and backgrounds
 - To better understand the nucleus
- Proven techniques see nuclear effects in CH
 - Will apply them to C, Fe, Pb
- Direct comparison of ν_e to ν_μ cross sections
 - Will get even better statistics in current run
- Developed ν -electron scattering technique for best constraint on ν flux
 - Expect to get to 5% precision on flux: a first for neutrino experiments!



Phys. Rev. Lett. 116, 071802 (2016)



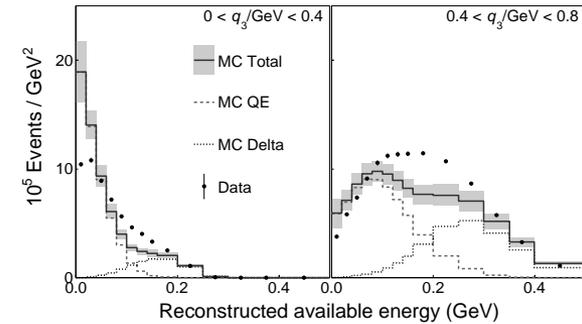
Phys. Rev. Lett 116, 081802 (2016)



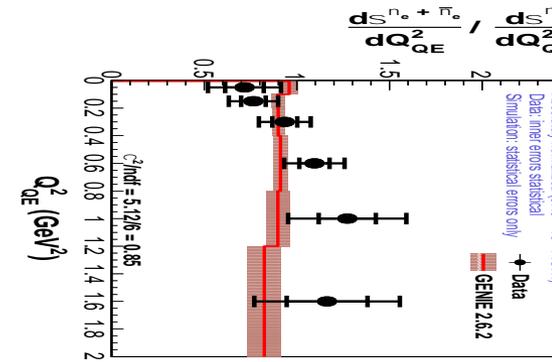
Phys. Rev. D 93, 112007 (2016)

MINER ν A status

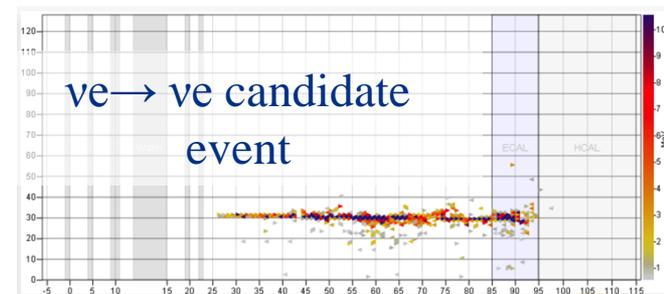
- 17 publications so far on low energy data set, more to come
- Running in medium energy beam since 2013
 - First results from that beam in FY17
- Have integrated > 3x the protons on target in neutrino mode compared to low energy run
- Detector running well, DAQ upgrade to make readout faster just completed
- Looking forward to antineutrino data later this year and beyond
 - CP violation measurements need precise antineutrino AND neutrino cross sections!



Phys. Rev. Lett. 116, 071802 (2016)



Phys. Rev. Lett 116, 081802 (2016)



Phys. Rev. D 93, 112007 (2016)

LArIAT

Study LArTPC response to neutrino interaction products (p , π^\pm , μ^\pm , e^\pm , γ , K^\pm) and measure hadron interaction cross sections

- **Analyzing Run-I + Run-II data**
 - First π -Ar total cross section measurement presented (publication in preparation)
- **Preparing for Run-III (Feb. – Jul. 2017)**
 - Impact of TPC wire pitch on particle ID
 - Direct comparison of 5, 4, & 3 mm pitch
- **Training the next generation of LArTPC experts**



SBN progress



Far detector building – Nov. 26



Near detector building – Nov. 26



LAr dewars arrive at FNAL from CERN

- ICARUS refurbishing progressing at CERN:
 - 1st TPC complete Jan 2017, 2nd in March 2017
 - Ship in April for installation in summer 2017
- SBND construction started in UK, US and CH
 - Assembly in 2017, installation in 2018
- Buildings progressing well:
 - Far detector: beneficial occupancy Dec 15th
 - Near detector: complete early 2017
- Joint SBN physics analysis group started Oct
 - About 50 attendees at first meeting



1st ICARUS cryostat ready for TPC at CERN - Nov. 2016



Inspecting ICARUS TPC at CERN Nov



ICARUS cold vessel
and new PMTs at
CERN

ICARUS arrives at
Fermilab Spring 17



Carlo Rubbia
ICARUS Spokesperson



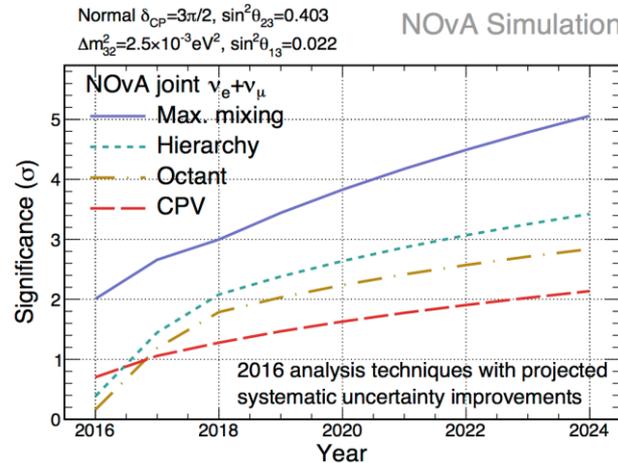
NOvA status

- New Results Presented in July

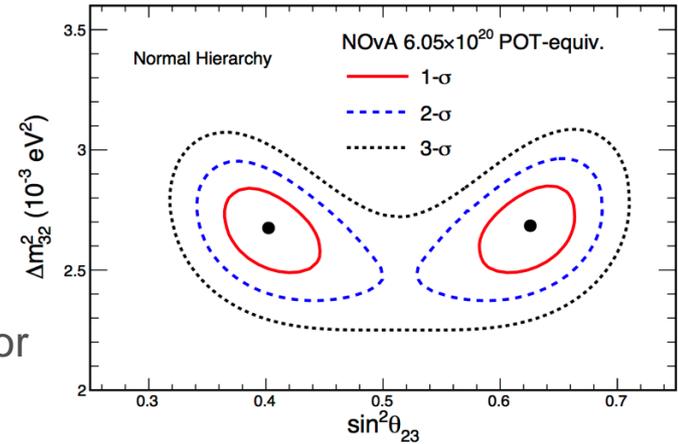
- Muon neutrino disappearance disfavors maximal mixing of muon and tau neutrinos at 2.5σ .
- 33 electron neutrino events at Far Detector, with reactor θ_{13} constraint and NOvA ν_μ disappearance, disfavors at $> 3 \sigma$ Inverted Hierarchy for δ_{CP} near $\pi/2$, for θ_{23} in lower octant.
- Initial limits on sterile neutrinos in long-baseline neutral current disappearance search.

- NOvA will take anti-neutrino data starting early CY17 to maximize progress on Mass Hierarchy, CP violation

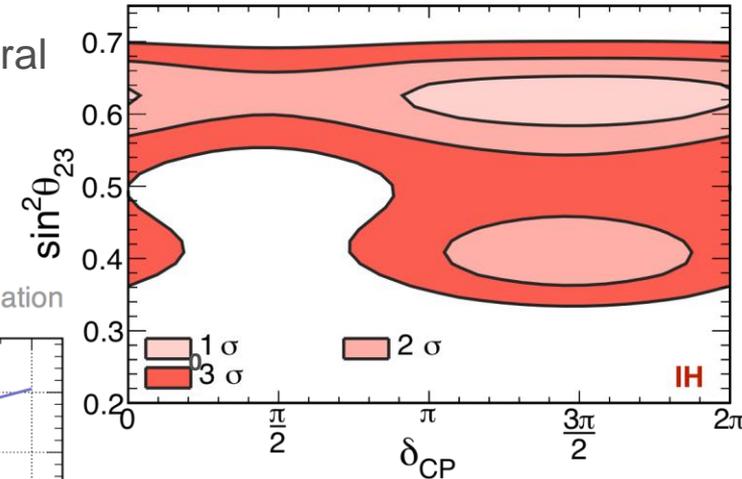
- Evolution of NOvA sensitivities assuming *Lisi et al.* best global fit parameters assuming equal neutrino/anti-neutrino running going forward.



NOvA Preliminary



NOvA Preliminary



Investigations underway to advance 3σ threshold for Mass Hierarchy by 1 year with accelerated beam delivery.

Muon Campus: Preparing for first data

Muon Campus Facts:

- Home to Muon g-2 & Mu2e experiments
- Shared cryo facility, beam delivery, etc.
- Each collaboration has ~200 members
- First muon is expected in April

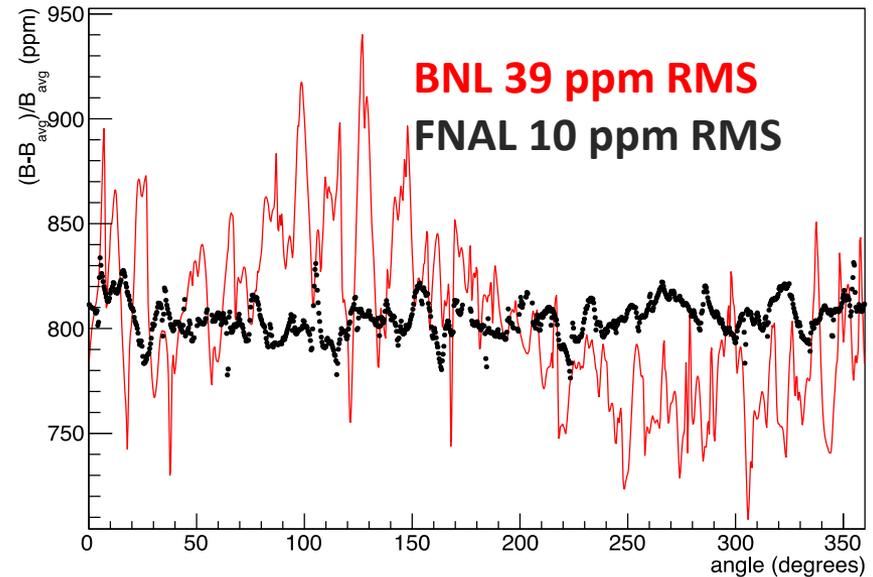


Fermilab's Muon Campus, October 2016

Muon g-2

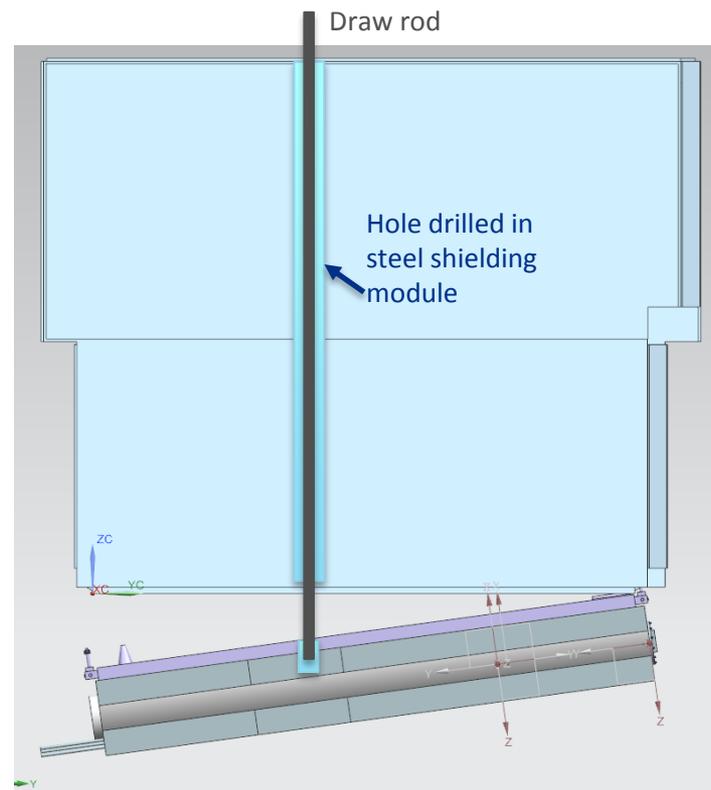
- Field team recently completed shimming the magnetic field
 - 4x improvement in azimuthal uniformity compared to BNL
- Work continues as rest of experiment is built around ring
 - Injection and muon storage: kicker, quadrupoles, inflector
 - NMR: Fixed probe, trolley, and calibration
 - Detectors: Calorimeters, trackers, electronics, and DAQ
- Major milestone 2 weeks ago...the BNL inflector was commissioned
 - ‘Other’ superconducting magnet from E821...had to work and it did for first time in 15 years

Dipole Vs Azimuth



Muon g-2

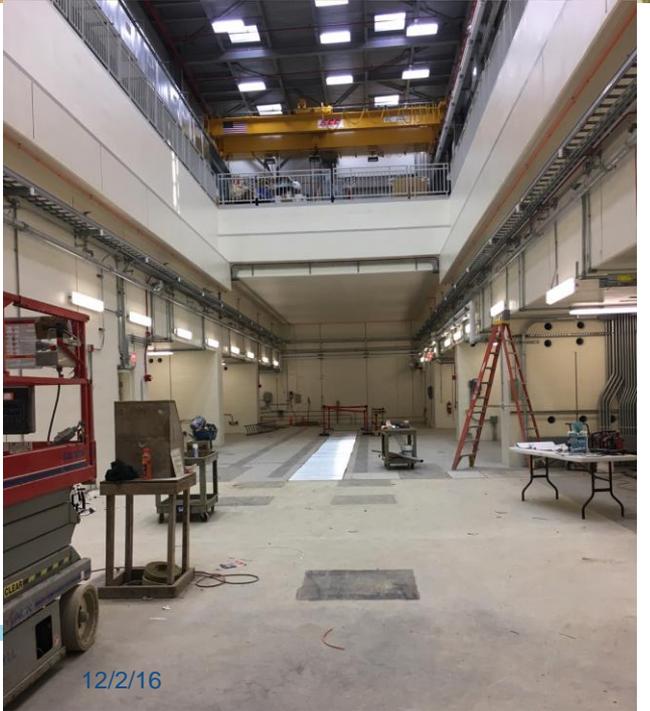
- Muon beam progress
 - Pbar dump successfully extracted after major effort to re-secure dump to shielding block
 - Last section of beamline to bring muons from the Delivery Ring to the g-2 storage ring under construction
- Anticipate experiment to be ready and beam commissioning to start in April 2017
- BNL sensitivity by Fall 2017



The Mu2e building is essentially complete



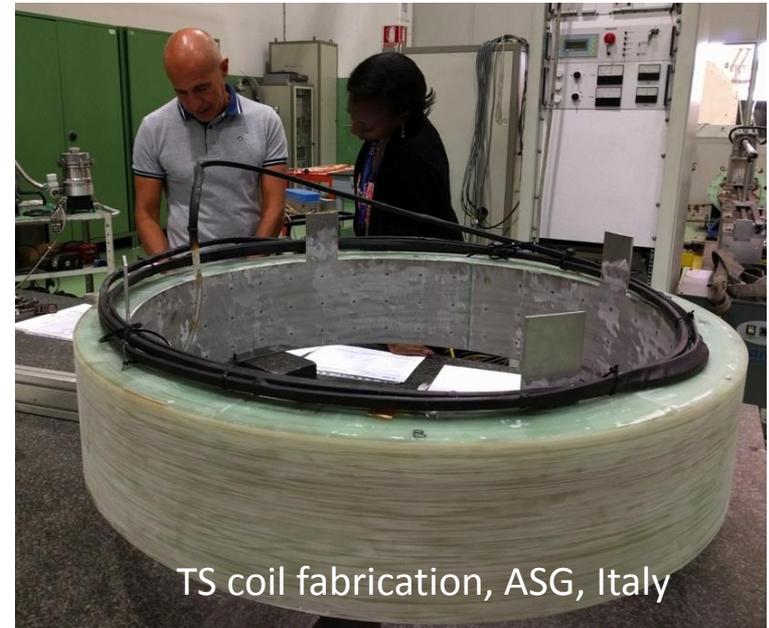
Beneficial Occupancy yesterday!



Mu2e: Solenoids



- All the conductor needed to build the Mu2e solenoids has now been fabricated.
- Coil winding has begun in Italy for the transport solenoid.
- The Muon Campus cryo facility is being finished to receive Mu2e solenoids.



Mu2e – HAB cryo facility



- CDF cryo facility refurbished as a test stand for Transport Solenoid Modules.
- Test cryostat ready to go

Detector prototypes

Tracker prototype

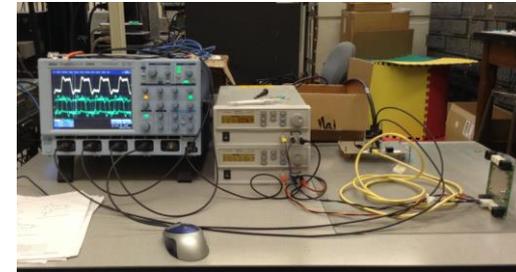


Cosmic Ray Veto prototype

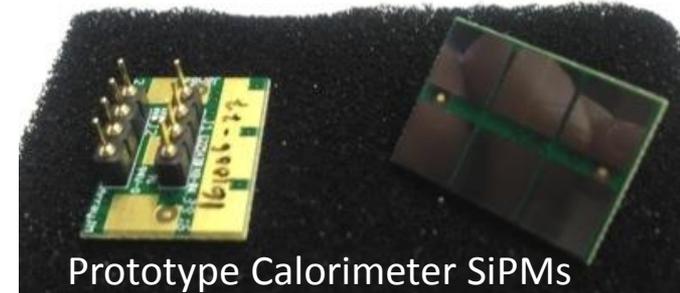
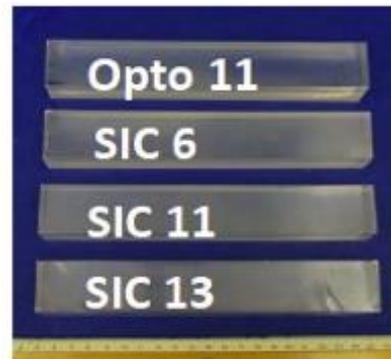


Prototype readout Controller

Prototype pixel readout for extinction monitor



Prototype Calorimeter Crystals

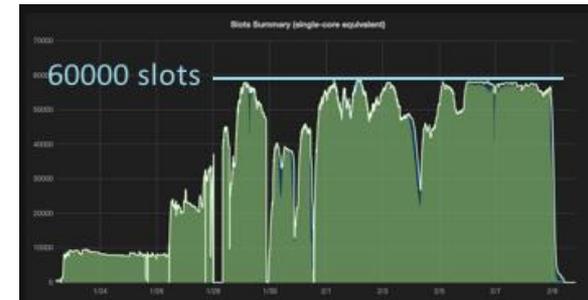
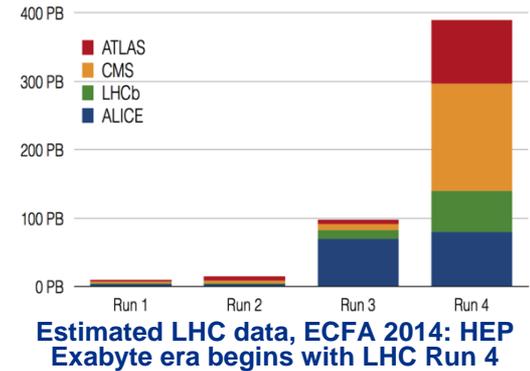


Prototype Calorimeter SiPMs

Computing & sensors

HEP Computing for the Future

- To meet the data challenges in the next decade requires a paradigm change in HEP computing
 - expected shortfall x10-x100 by 2025
 - will have to exploit next-generation hardware and computing models
- HEPCloud provides a common interface to local, grid, HPC, and cloud computing, to achieve facility elasticity
 - Allows HEP to own baseline resources and to use HPC and cloud resources for peak
- Focusing on expanding HPC utilization beyond traditional LQCD, Cosmology, and Accelerator Modeling applications
 - Multi-threaded CMS and art software frameworks, MicroBOONE and CMS production workflows at NERSC, Pythia at ALCF. More planned for 2017...



Full simulation of CMS events for Moriond 2016 with HEPCloud and Amazon Web Services



Doubling global CMS computing and generating 1B events in 48 hours with HEPCloud and Google

Virtual Reality from Fermilab



MicroBooNE VR on Capitol Hill



CMS VR at Supercomputing 2016



Natl Society of Black Physicists



Users Meeting

ATLASrift was pioneer

Moving from education tool to advanced data visualization

Open source



Universities

Snapshot of Fermilab user community in FY16

- **3245**: Total number of Fermilab users
- 2242: Users of the Fermilab proton accelerator complex
- 1003: Users of Fermilab's CMS facility
- 521: Number of institutions represented
- 37: Number of countries represented including US
- About equally split between users that came to Fermilab in FY16 (1604) and those that accessed our facilities remotely (1641)

New Fermilab Distinguished Scholars Program

Rotating multi-year appointments for U.S. theorists in Fermilab's theory departments, with one month/year in residence.



A. El-Khadra
(UIUC)
Lattice QCD



P. Huber
(Virginia Tech)
Neutrinos



A. Nelson
(Washington)
BSM



D. Wackerath
(Buffalo)
Perturbative QCD

- Strengthens connections between U.S. university and Fermilab theorists...new collaborations emerging
- Increases local theoretical expertise in areas that support Fermilab's experimental program
 - El-Khadra and Fermilab lattice theorists spearheading a new $g-2$ theory initiative
 - Wackerath and Fermilab pQCD and neutrino theorists co-organizing 2017 workshop(s) on precision perturbative calculations for neutrino experiments



Neutrino Physics Center: <http://npc.fnal.gov>

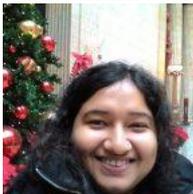
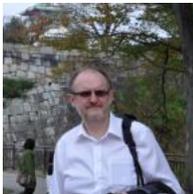
The NPC enables researchers from around the world to visit Fermilab and participate in the expanding neutrino program.

The Center is for the neutrino community and organized by the community.

Coordinators: Bonnie Fleming, Debbie Harris & Stephen Parke

Activities: Nu Fellows, Nu Seminar, Nu University, Nu Workshops, Int. Nu Summer School 2017

NPC Fellowship Statistics	Spring 2016	Fall 2016
Total Applicants	42	30
Total Awards	31 (photos)	20
Total \$ awarded	184 k	134 k
Masters Students	5	2
PhD Students	9	5
Postdocs	6	8
More Senior	11	5



The LHC Physics Center (LPC) at Fermilab

- The LPC continues to be an outstanding center of excellence for US-CMS and for CMS – it has been championed by the CMS collaboration
- It is vibrant, stimulating, and making everybody around more productive through its variety of programs and activities including trainings, workshops, seminars



- The LPC is steadily growing in its attractiveness within our CMS community
 - US: All 50 institutions on CMS take advantage of it
 - International: Used by many countries in Latin America, Asia, and Europe

LPC Recent News

- LPC selection of 2017 Distinguished Researchers
 - 21 New DRs: 8 seniors (faculty); 13 juniors (postdocs)
 - Most are from institutions in the US; several are from UK, Italy, Germany, India, and Korea
- Latest selection of guests and visitors includes physicists from the US, Brazil, China, Colombia, Ecuador, India, Italy, Mexico, and Turkey
- Workshops held recently at the LPC
 - Most are CMS-internal, e.g. HCAL Simulation, Phase 2 Readiness for Physics, Jet Substructure etc
 - 8th INFIERI Workshop (INtelligent, Fast, Interconnected and Efficient devices for Frontier Exploitation in Research and Industry)



8th INFIERI Workshop
17-21 October 2016
LPC@FNAL

INtelligent, Fast, Interconnected and Efficient Devices for Frontier Exploitation in Research and Industry

- Review of INFIERI status and perspectives
- Focus on collaborative links with FNAL partner
- Review Talks on main FNAL research streams and projects
- Outreach: visits to SiDet, g-2 and Test beams at FNAL

<http://bit.ly/2cHltvQ>
<http://infiери-network.eu>

The poster features a collage of images including a person's face, a particle detector component, and various logos of partner institutions such as CERN, INFN, THALES, and PHILIPS.

2017: Fermilab's 50th Anniversary

Building relationships for the next 50 years



Decision Makers

Jan 27: Local reception before history lecture

April: DC reception with Board meeting

Sept 23: Regional/state VIP tours

Scientific Community

June 7: 50th Anniversary Symposium

June 15: Partners celebrate with us online

Sept 23: Partners participate in Open House

Public

Jan 21: Public event for Arts Series attendees

Spring/Summer: Outreach events across Greater Chicagoland

Sept 23: Science & Innovation Open House

Employees & on-site users

Jan: All-hands kickoff meeting and cake

June 15: Celebration on Fermilab's 50th birthday

Dec: Enhanced end-of-year party

Alumni

June 7: 50th Anniversary Symposium

Sept 23: Special invite + perks at Open House

All year: Collecting stories, contact info for future initiatives

DOE:

- This is a good time to acknowledge the tremendous support that we have received from DOE Secretary Ernie Moniz, Under Secretary Lynn Orr, and Director of the Office of Science Cherry Murray
- In addition to these DOE political appointees, we owe a great debt to Pat Dehmer, who retired this month, for her outstanding stewardship of the Office of Science
- Supportive DOE site office, headed by Mike Weis
- Great support from DOE HQ on many fronts, including international partnerships

Summary

- LBNF preparing to start initial far site construction this year
- DUNE collaboration expected to hit 1,000 at Jan. meeting
- Rapid progress on ProtoDUNE construction at CERN
- NOvA moving to antineutrino running
- SBN, Muon g-2, Mu2e construction advancing
- CMS Phase 1 upgrades on track for installation this winter; CD-0 for Phase 2 upgrades
- DES going strong; SPT-3G cryostat camera delivered to South Pole
- HEP computing moving into the future: cloud, HPC
- Fermilab serves 3,245 users; centers and fellowships increasing collaboration with university community

Questions?