



# Fermilab Report

Joe Lykken

Deputy Director and Chief Research Officer

HEPAP meeting

12/9/2014

# Outline

---

- Pushing forward with the P5 plan
- Projects completed, projects moving ahead
- Organizational changes to support top P5 priorities
- Addressing new initiatives blessed by P5
- Progress on the new international neutrino program

# P5 plan for US HEP in a nutshell

---

(my personal attempt at a one slide summary)

- Continue our commitment and leading roles in the LHC
- Build a neutrino program that will attract the world community
- Continue leading efforts in dark matter, cosmic surveys, and CMB
- Invest in the accelerator and detector technologies that we will need in the future

It is a feature of this plan that the major components reinforce each other



- Fermilab is already fully aligned with the P5 plan
- Now, with the community, we are focusing on execution
- There are many challenges:
  - Limited resources and uncertainty about budgets
  - Strengthening international partnerships and making them work within the DOE system
  - Stepping up our game on project management across portfolio
  - Proton economics of FNAL accelerator operations
  - Strengthening our user community, ties to universities and other labs
  - Lab infrastructure aging, not optimized for future needs
  - Uncertainty about GARD (waiting for the subpanel report)

# Projects completed, projects moving ahead

---

- NOvA CD-4 Sept 2014 ✓
- CMS phase 1 upgrades CD-2/3 ESAB Nov 2014 ✓
- MicroBooNE CD-4 expected Dec 2014
- Mu2e CD-2/3b expected early 2015
- Muon g-2 CD-2/3 expected spring 2015
- LBNF CDR (supporting existing CD-1) expected summer 2015
- SuperCDMS SNOLAB, CD-2 hoped for by end of 2015
- PIP-II pre-CD-0 but projectized management of R&D
- CMS phase 2 upgrades pre-CD-0 but projectized management of R&D
- HL-LHC accelerator is pre-CD-0 but attempting international CRADA with CERN for Nb<sub>3</sub>SN magnet conductor
- + LCLS-II + DESI + SLI projects

List limited to US projects with significant FNAL involvement in project management

# NOvA

## A broad physics scope

Using  $\nu_\mu \rightarrow \nu_e$ ,  $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$  ...

- Determine the  $\nu$  mass hierarchy
- Determine the  $\theta_{23}$  octant
- Constrain  $\delta_{CP}$

Using  $\nu_\mu \rightarrow \nu_\mu$ ,  $\bar{\nu}_\mu \rightarrow \bar{\nu}_\mu$  ...

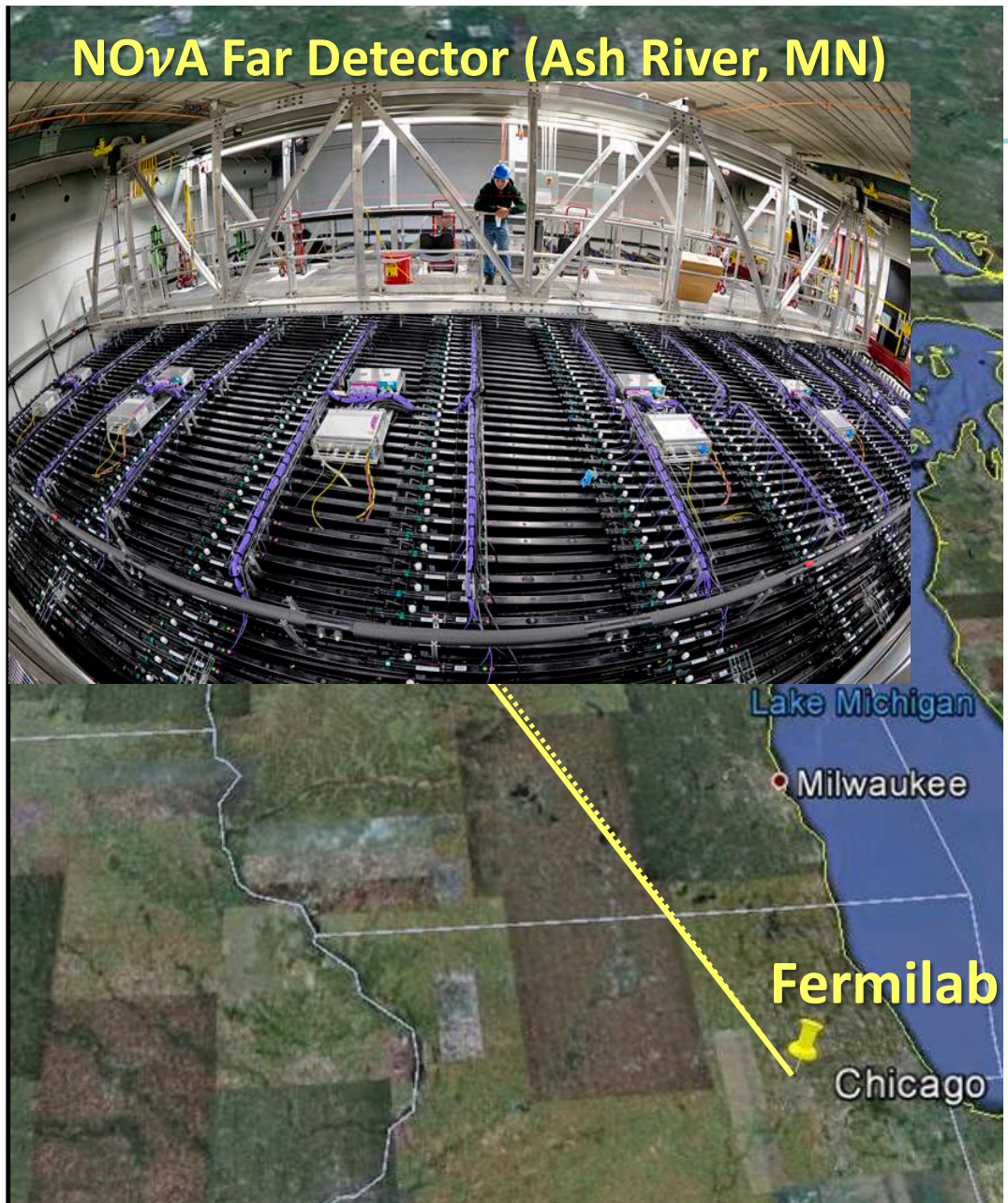
- **Atmospheric parameters:** precision measurements of  $\theta_{23}$ ,  $\Delta m_{32}^2$ . (*Exclude  $\theta_{23} = \pi/4$ ?*)
- **Over-constrain** the atmos. sector (*four oscillation channels*)

**Also ...**

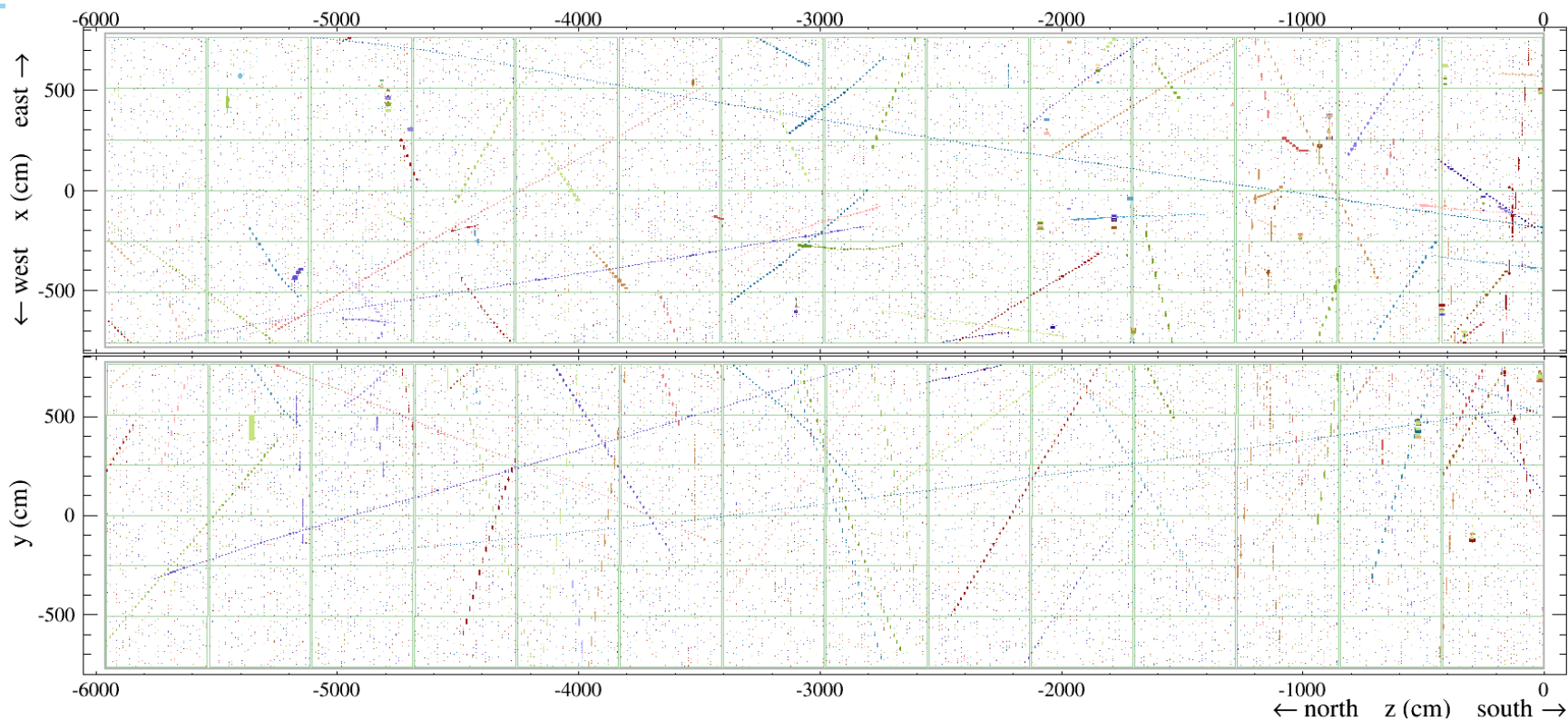
- Neutrino cross sections at the NOvA Near Detector
- Sterile neutrinos
- Supernova neutrinos
- Other exotica

Ryan Patterson, Caltech

## NOvA Far Detector (Ash River, MN)

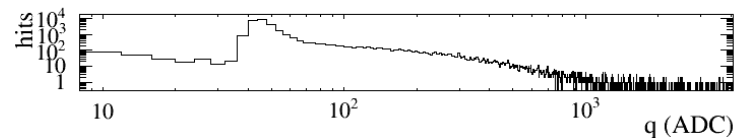
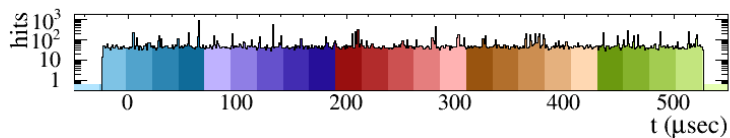


# Raw data from 500 $\mu\text{s}$ of Far Detector activity



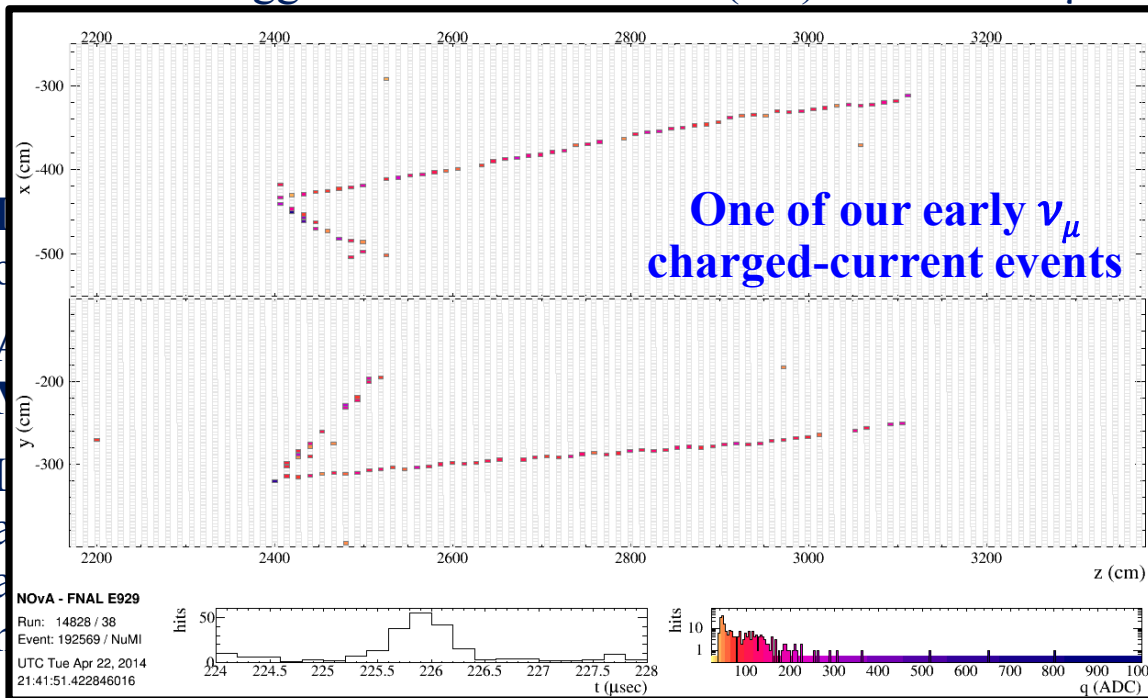
## NOvA - FNAL E929

Run: 16674 / 15  
Event: 68101 / NuMI  
UTC Fri Aug 8, 2014  
19:12:22.145823424



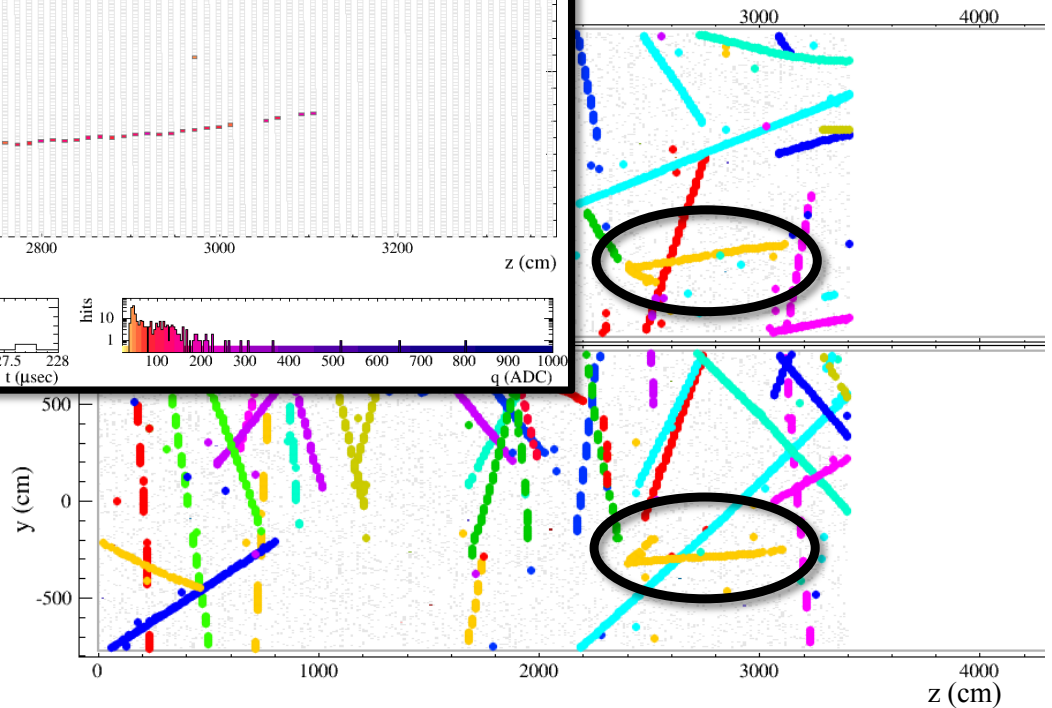
# Isolating individual interactions

- A standard trigger in the Far Detector (FD) records 550  $\mu\text{s}$  of activity: (as low as possible)



physics events isolated

- According to FD simulation:  
**Avg. completeness: 99.3%**  
**Avg. purity: 99.5%**  
*(Actually improved beyond this now...)*

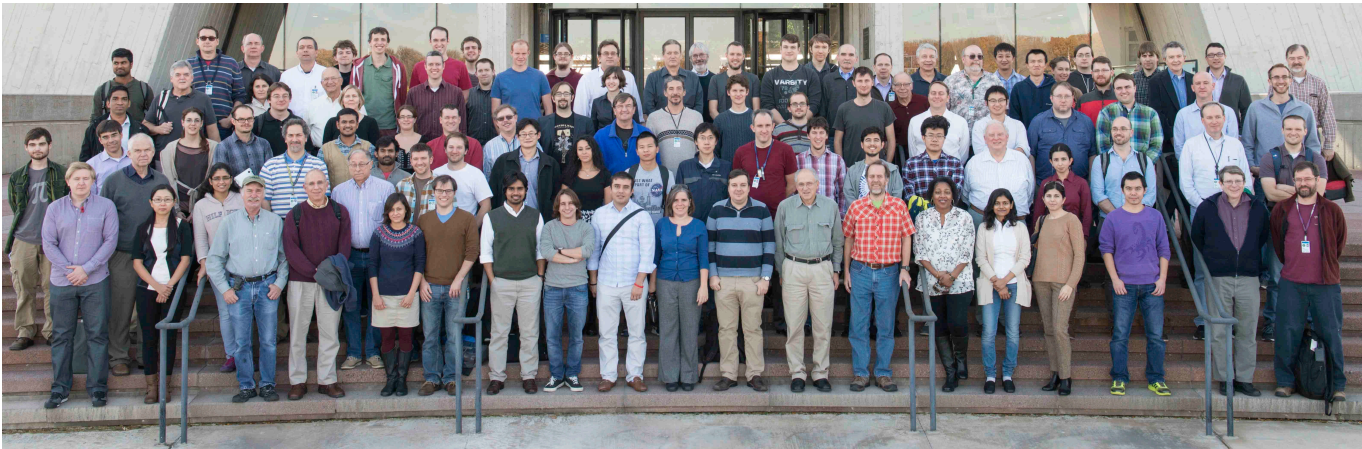






# NOvA Collaboration

- 129 PhD physicists, including 35 from foreign countries
- 50 graduate students, including 13 from foreign countries
- 38 Institutions, including 17 from 6 foreign countries:
  - Brazil, Czech Republic, Greece, India, Russia, United Kingdom



Gary Feldman

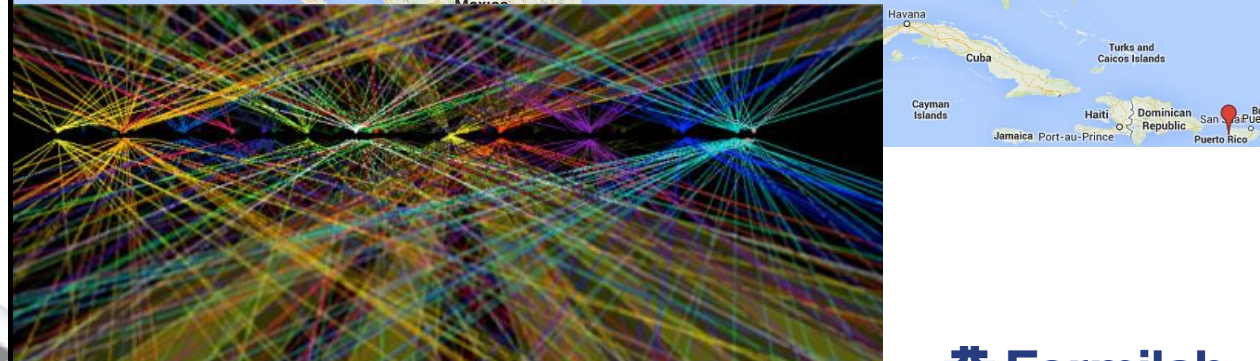
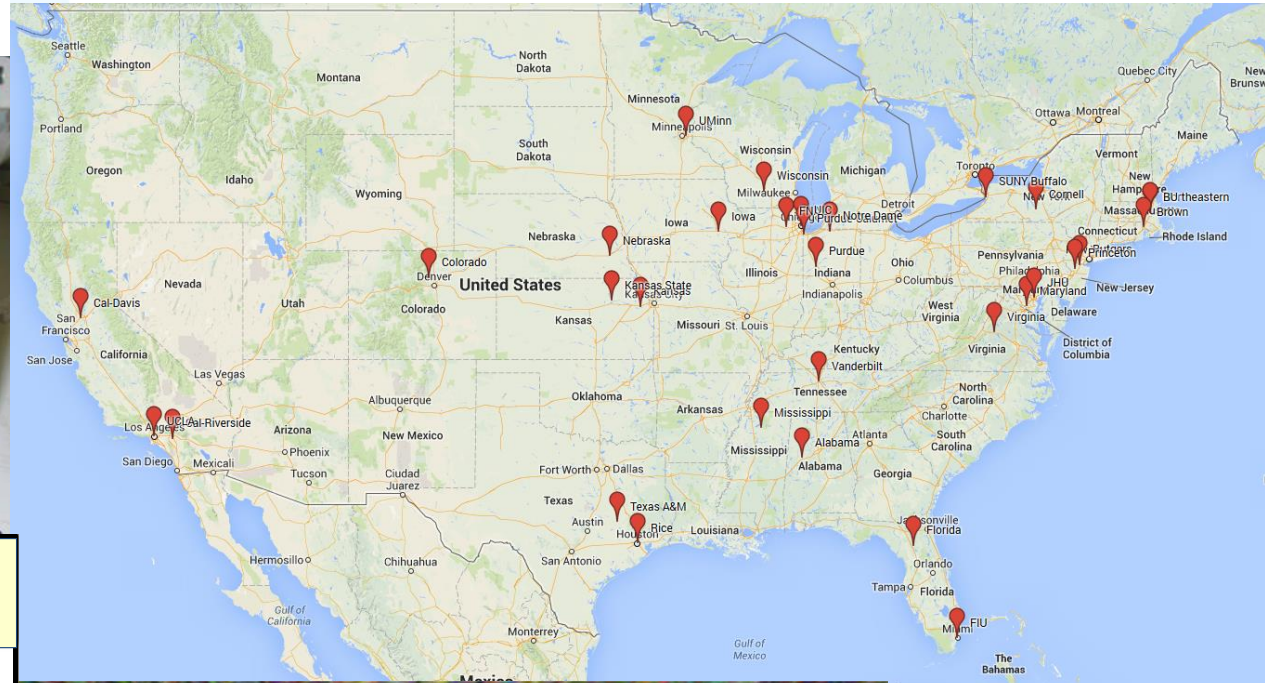
NOvA Readiness Review

28 October 2014

8

# CMS phase one upgrades

- ~30 Institutions, both NSF and DOE,  $O(\$40M)$



**Forward Pixel  
Detector (FPiX)**

**FPiX: 44.7M Pixels  
0.7m<sup>2</sup> active area**

# CMS phase one upgrades



# MicroBooNE



# MicroBooNE





# Mu2e

---

Lots of new interest since P5 report: discussions with 15 new U.S. groups plus U.K., S. Korea, and Germany

New groups for collaboration meeting last week:

- Novosibirsk
- Louisville
- So. Alabama
- Argonne
- Minnesota
- Yale
- + 5 new collaborators from NIU and FNAL



# Lab infrastructure

---

Science Laboratories Infrastructure (SLI) is a DOE program outside of DOE HEP that enables lab infrastructure projects.

Fermilab initiatives:

- UUP, seeking CD-2, and IER, seeking CD-0, both Dec 2014

Part of longer term campus strategy:

- Improve operational efficiency by replacing aging systems, buildings that are functionally obsolete and geographically dispersed
- Improve and modernize Fermilab user experience

Center for Integrated Engineering Research (IER)





# Lab infrastructure

---

- Wilson Hall improvements ongoing
  - Integrated space for Neutrino Division
  - Improved PPD user space
  - Users Office: Mines of Moria -> SW corner of Atrium

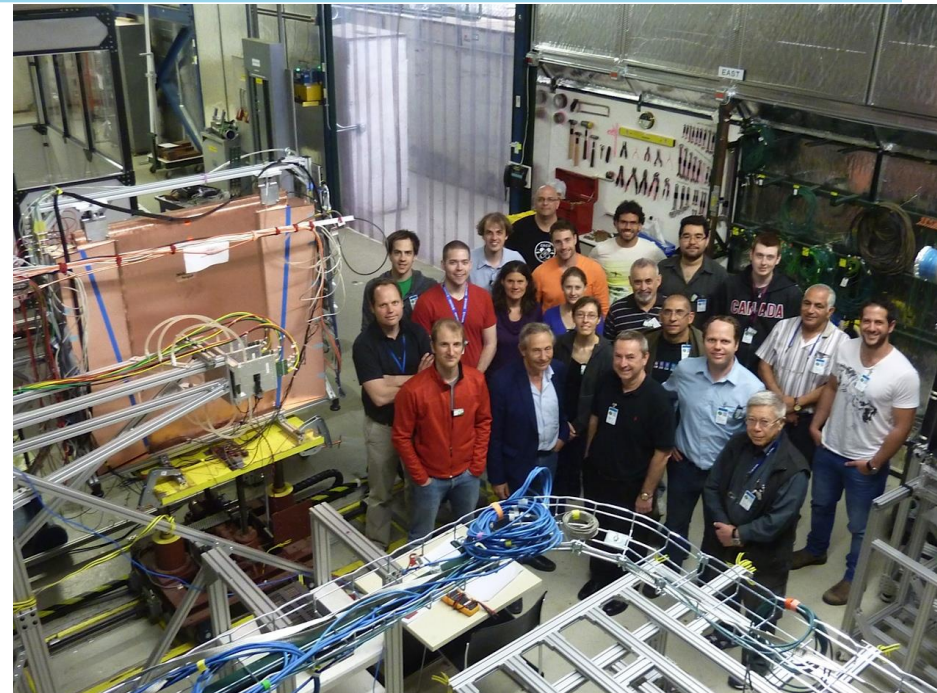
- ROC West in operation since October



# Test beam facility

- T1015 DRO Calorimetry
- T1037 FLYSUB-Consortium
- T958 FP420 (CMS+ATLAS) Fast Timing Group
- T979 Fast Timing w/Cherenkov Counters
- T989 DAMIC
- T1058 Secondary Emission Calorimeter
- T1031 Atlas Tile Calorimeter Electronics
- T1036 CMS High Rate Pixel Detector
- T1041CMS Forward Calorimetry
- T1049 ATLAS large scale TGC
- T1056 ATLAS DBM Module Qualification
- T992 Radiation-hard Sensors for the SLHC
- T1042 Muon g-2 straw tracker
- T1018 Spacordion Tungsten Fiber Calorimeter
- T1044 sPHENIX
- T1048 PHENIX fast TOF
- T1054 sPHENIX Pre-Shower Calorimeter
- T994 JASMIN

Two Large Neutrino experiments on schedule for FY15: MINERvA & LARiaT



## Test beam users in FY14:

- 321 collaborators
- 18 experiments
- 84 institutions
- 20 countries

# Organizational changes to support top P5 priorities

Neutrino Division: home for both the short and long baseline programs, experiments, operations, projects

- Went live Oct 1, Gina Rameika leading
- Growing, reorganized space in Wilson Hall
- LBNE moved out of the CDF trailers



Particle Physics Division: home for CMS, Muon program, Cosmic Frontier, Theory,

- Patty McBride leading
- “Initiatives” Dept headed by Dmitri Denisov
- Stronger “projectized” management of CMS phase 2 upgrades: led by Vivian O’Dell



Stronger lab-wide project support and planning, led by Mike Lindgren



# P5 top priorities: HL-LHC

## CMS Phase 2 Upgrades: mitigate PU and radiation damage

Tracker: Pixels and Strips → Inner and Outer

- Radiation tolerant - high granularity - less material
- Tracks in hardware trigger (L1)
- Coverage up to  $\eta \sim 4$

Endcap Calorimeters

- Radiation tolerant - higher granularity
- Investigate coverage up to  $\eta \sim 4$

Barrel ECAL

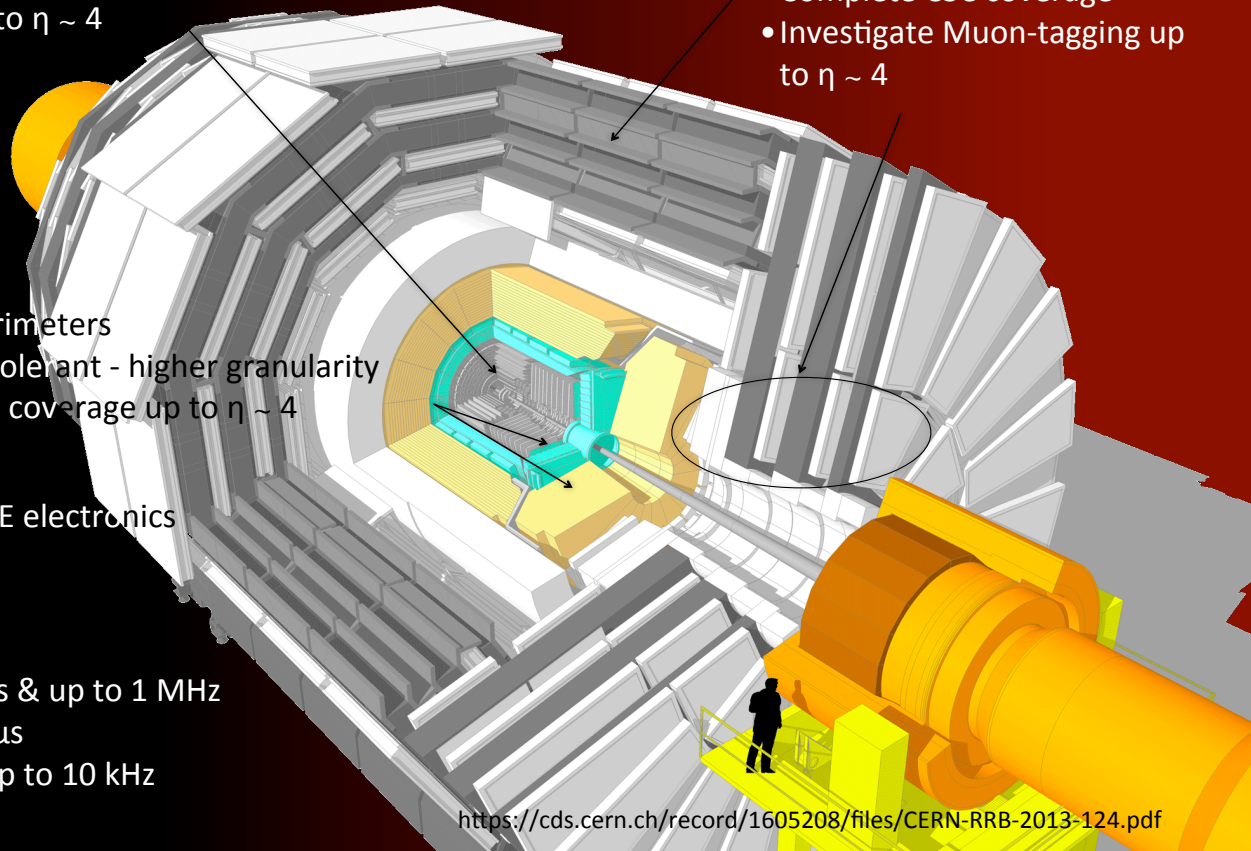
- Replace FE electronics

Trigger/DAQ

- L1 with tracks & up to 1 MHz
- Latency  $\geq 10\mu\text{s}$
- HLT output up to 10 kHz

Muons

- Replace DT FE electronics
- Complete CSC coverage
- Investigate Muon-tagging up to  $\eta \sim 4$



<https://cds.cern.ch/record/1605208/files/CERN-RRB-2013-124.pdf>

# HL-LHC schedule



## Timeline for Phase 2

- Schedule defined by
  - R&D and technical decisions → TDRs by end 2016 / early 2017
  - LHC performance (Phase 1 longevity < 500 fb<sup>-1</sup>) and HL-LHC schedule (LS3 shutdown)

CMS Schedule Outline (calendar years)

2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
TP											
Technology R&D											
		TDRs									
	Design and Prototyping										
			Engineering Design								
			Pre-Production								
			Production/Construction								
								Install/Commission			

Implication for US (FY)

2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
R&D Funding											
			Pre-production orders (sensors, photodetectors...)								
			Production orders, Construction and Assembly								

# Addressing new initiatives blessed by P5

---

## G2 Dark Matter

- Working with SLAC on SuperCDMS SNOLAB project management
- Two Fermilab scientists have joined LZ : Hugh Lippincott and Eric Dahl
- Several FNAL scientists have asked to join ADMX
- Still providing modest ops support to COUPP/PICO, Darkside, DAMIC

## DESI

- Brenna Flaugher is DESI Project Scientist
- DESI eventually replaces DES as main Fermilab dark energy effort

## LSST

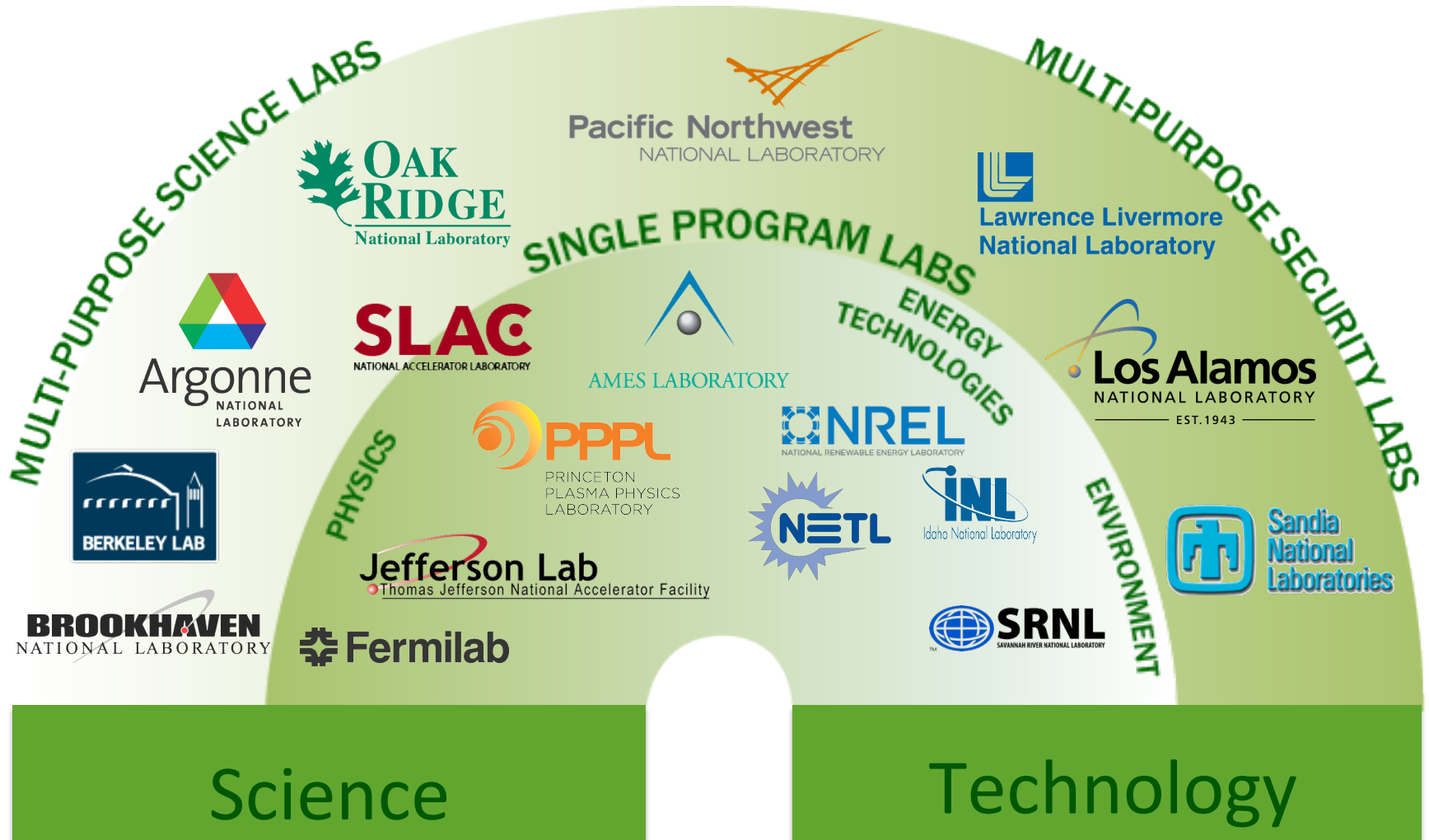
- Involved through the Dark Energy Science Collaboration

## CMB

- Partnered with U. Chicago and Argonne on SPT-3G
- Using LDRD to explore options for CMB-S4 in concert with other labs

**Mapping appropriate FNAL expertise and resources to community led initiatives**

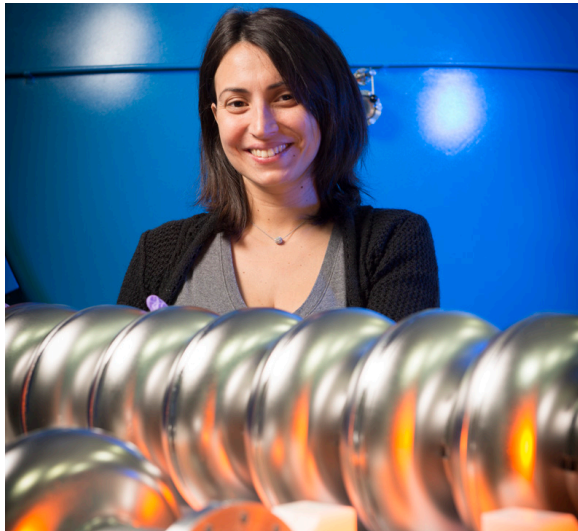
# The National Labs as Networks



# The National Labs as Networks - Example: LCLS-II

---

- Fermilab, Argonne, Jefferson Lab, and Berkeley Lab all working to build the next generation LCLS-II light source at SLAC
- Fermilab's expertise in SRF cavities is essential
- Highest gradient cryomodule in the world is at Fermilab
- Highest Q cavities in the world are at Fermilab

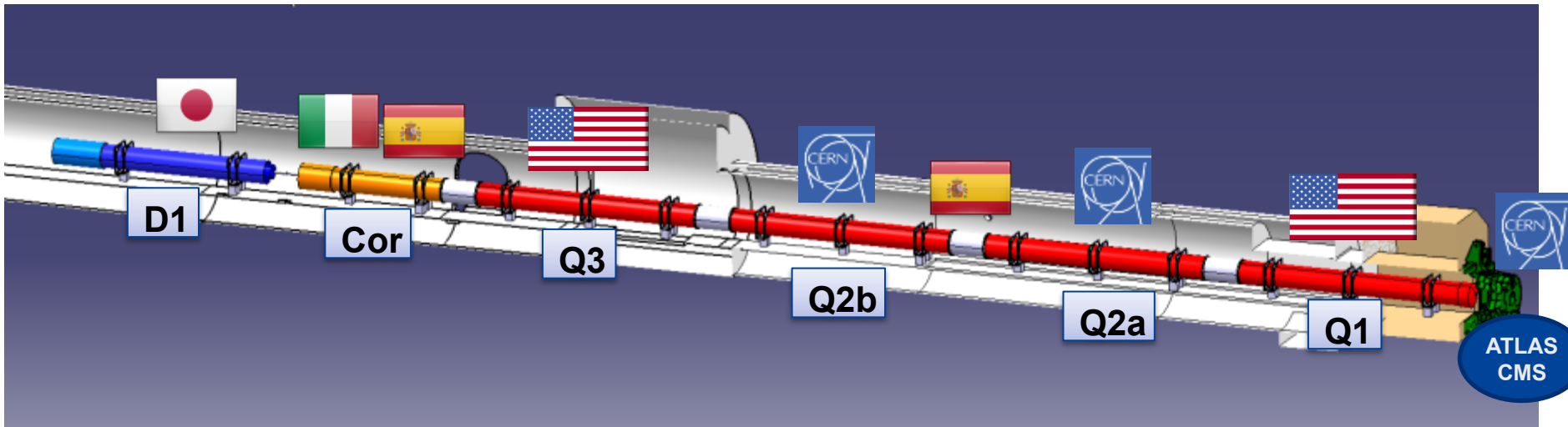


- After LCLS-II is done, could keep building cryomodules, now for PIP-II
- Also involves multiple labs as well as **international** partners
- Enables the world's most powerful neutrino beam



# The National Labs as Networks - Example: HL-LHC

- Fermilab, BNL, LBNL and SLAC all working on HL-LHC accelerator upgrades
- Part of a larger **international** network of labs



# P5 top priorities: Neutrinos

---

**Recommendation 12: In collaboration with international partners, develop a coherent short- and long-baseline neutrino program hosted at Fermilab.**

**Recommendation 13: Form a new international collaboration to design and execute a highly capable Long-Baseline Neutrino Facility (LBNF) hosted by the U.S. To proceed, a project plan and identified resources must exist to meet the minimum requirements in the text. LBNF is the highest-priority large project in its timeframe.**

- A big commitment by the US HEP community
- Basically asks Fermilab to do for neutrinos what CERN did for the Higgs, involving the worldwide community
- It will be a heavy lift, especially on the international side
- But we have to make it happen

# P5 neutrino mandate for Fermilab

---

- Encourage formation of a new international collaboration to build large liquid argon detectors deep underground
- Provide a  $> 1$  megawatt neutrino beam for LBNF (PIP-II)
- Develop a short baseline neutrino program that advances liquid argon R&D

The short baseline program should be coherent with both LBNF and non-Fermilab based neutrino efforts

## P5 Headline: Particle Physics is Global

---

- This was not highlighted in previous HEPAP reports
- US HEP plan needs to make sense in the context of global HEP
- US involvement in LHC seen as a successful example of international collaboration
- International partnerships of growing importance in US science, HEP seen as leading the way

# European strategy

---

- Highest priority is exploitation of the LHC including luminosity upgrades
- Support at CERN for European involvement in neutrino experiments in the US



- **Combination strengthens the US-European partnership for HEP**
- **Note the strong CERN-Fermilab partnership is key here**

# LBNF and a new international collaboration

---

- June: CERN Medium-Term Plan approved...5 year plan with next year's budget defined...\$60M for neutrinos
  - Aimed at neutrino platform to assist with program in US
  - Marzio Nessi leads development of the neutrino platform
  - Investment in infrastructure outside CERN allowed
- June 21-22: APPEC Paris meeting...European neutrino physicists & agencies met to discuss future
  - Strong support for accelerator-based neutrinos in US & Japan
- July 14: Jim Siegrist hosted a meeting at Fermilab of funding agencies....UK, Italy, CERN, India, Brazil, Japan
  - Launch working group to discuss international governance

# LBNF and a new international collaboration

---

- July 21-22 Neutrino “summit” at Fermilab
  - World neutrino community represented
  - Recommended creation of Interim International Executive Board (iIEB) to move forward on forming a new collaboration
- Sept. 23-24 First meeting of iIEB at Fermilab
  - Discussed scientific strategy for new experiment
  - Agreed to begin draft LOI aimed at January Fermilab PAC
- Oct 20 Phone meeting of iIEB
  - Agreed on Sanford lab as underground site, after Oct 8/9 visit
  - Agreed to call two open PI meetings to form new collaboration:
    - Dec 5 at CERN, Dec 12 at Fermilab

# LBNF and a new international collaboration

---

## Nov 22: Phone meeting of iIEB

- Agreed to choose an interim chair for the Institutional Board of the new collaboration
- Agreed on Jan 22-23 as dates for the first collaboration meeting
- Set up writing group for LOI
- Set up working group on collaboration governance, led by Chang Kee Jung and Stefan Soldner-Rembold



# LBNF and a new international collaboration

---

Nov 30:

Sergio Bertolucci named interim IB chair for the new collaboration

- Will lead the presentation of the LOI to the Fermilab PAC
- Will call and chair the first collaboration meeting

# LBNF and a new international collaboration

---

## Dec 5: Neutrino open meeting at CERN

- Informational meeting for prospective PIs of the new collaboration
- Chaired by Rob Roser (Ken Long), participation by leaders of both the European and US neutrino communities
- Nigel Lockyer, Sergio Bertolucci, Fabiola Gianotti present to encourage the process to move forward

## Next Steps for LBNF

---

- Dec 12: Neutrino open meeting at Fermilab
  - Twin of the Dec 5 meeting at CERN
- Dec 21: LOI delivered to Fermilab PAC
- Dec 21: Completion of whitepaper on international governance
- Jan 14-16: Fermilab PAC meeting
- Jan 22-23: First meeting of the new collaboration

### Other action items for first quarter of 2015:

- Collaboration elects its management (iIEB dissolves)
- Collaboration forms its own technical engineering group
- Collaboration launches working groups for CDR
- Formation of International Joint Oversight Group for LBNF

# Working group on international governance for LBNF

---

- An informal forum for discussions about the higher-level aspects of international governance for LBNF
- Coordinated with the iIEB, as a resource for international governance aspects of the LBNF proposal
- Deliverable is a short whitepaper describing a possible model for governance of LBNF with a strong international footprint
- Also highlighting issues requiring further attention

# Working group members and contacts

---

- Purniah Boddapati
- Carlos Henrique de Brito Cruz
- Jun Cao
- Brajesh Choudhary
- Paco Del Aguila
- Antonio Ereditato
- Josh Klein
- David Lissauer
- Joe Lykken (chair)
- Antonio Masiero
- Tony Medland
- Marzio Nessi
- Andre Rubbia
- Michael Salamon
- Jim Strait
- Robert Svoboda
- Agnieszka Zalewska

Have also gotten valuable information and feedback from

- Sergio Bertolucci
- Mike Procaro

Other feedback is welcome!

# International Governance of what?

---

A long baseline neutrino program hosted by Fermilab, with one or more large LAr far detectors deep underground at the Sanford Lab, and one or more near detectors in the  $>1$  MW neutrino beamline at Fermilab

- An international science collaboration (placeholder name “ELBNF”), which will design, build, operate, and do scientific research with a system of neutrino detectors, and also enable other research opportunities such as searches for baryon number violating processes and neutrino astrophysics.
- A Long Baseline Neutrino Facility providing the neutrino beam that will illuminate the neutrino detectors, as well as conventional facilities and major technical infrastructure to support the beamline and the detectors.

# General observations

---

- The new international collaboration should develop the science strategy, design, and optimization of the experiment (“bottom–up process”). This will attract the best scientists and result in the best experiment.
- Bottom-up experimental design must iterate with funding agencies to make sure scope matches resources. This will require global coordination to ensure that resources are identified for all elements of the experiment

# The LHC model

---

We adapt the LHC model, with an international detector collaboration, a host lab providing infrastructure, and appropriate international oversight bodies

- The detector projects are in the hands of the new international collaboration, with appropriate oversight by stakeholders
- The LBNF facility infrastructure is a DOE/Fermilab project, in collaboration with international partners
- International oversight and coordination is provided by an International Joint Oversight Group (IJOG), and subsidiary groups:
  - Resource Review Board
  - Experiment-Facility Interface Group
  - Fermilab Physics Advisory Committee



# International Joint Oversight Group

---

- The International Joint Oversight Group (IJOG) will be made up of representatives from each funding agency involved in the neutrino program and provides global coordination across the entire enterprise
- During the formative stages of LBNF, the IJOG would develop the overall division of responsibilities for the construction of detectors and facilities, in the context of bi-lateral agreements and subsidiary agreements between DOE/Fermilab and other stakeholders

# Fermilab roles and responsibilities

---

Fermilab is directly responsible for the design, construction, installation, commissioning and operation of the facilities and infrastructure that support LBNF:

- The neutrino beamline
- The major technical infrastructure necessary to support the near and far detectors, including cryogenic systems and cryostats
- The conventional facilities for the beamline and near detector on the Fermilab site and for the far detector at the Sanford Underground Research Facility

Fermilab will work with international partners in designing and building these facilities

# Fermilab roles and responsibilities

---

As the host lab, Fermilab will provide oversight for both the facility and detector construction projects, through mechanisms including

- Regular meetings with Collaboration leadership
- Convening and chairing the Resource Review Board(s)
- Convening international peer review by the Fermilab Physics Advisory Committee
- Convening meetings of the Experiment-Facility Interface Group
- Director's reviews of specific management, technical, cost, and schedule aspects of the construction projects

# Collaboration roles and responsibilities

---

The new Collaboration is a self-organized entity bringing together scientific groups from around the world to perform this experiment. It is responsible for:

- The formulation of the scientific strategy and corresponding scientific and technical requirements on the detector systems and neutrino beam line
- The design, construction, installation, commissioning and operation of the near and far detector systems
- The scientific research program conducted with the detectors and LBNF neutrino beam

# Project management within the collaboration

---

- The management of the detector construction project will be delegated to a project management team chosen by the collaboration
- This team will be led by a Technical Coordinator and Resource Coordinator (the ATLAS/CMS model)
- The TC and RC are selected by the collaboration (with concurrence of Fermilab Director) and become Fermilab employees during the project
- The TC and RC report to the collaboration Spokespeople, and lead a project office in the Fermilab Neutrino Division

# Resource Review Board

---

To provide more focused monitoring of each of the two projects, the IJOG will create one or more Resource Review Boards (RRB), made up of representatives of that project's funding agencies and Fermilab management.

RRB roles include:

- Coordinating the development of international agreements
- Monitoring the Common Projects and the use of the Common Funds
- Monitoring the general financial and manpower support
- Resolving issues that may require reallocation of responsibilities among the project's funding agencies
- Endorsing the annual construction and maintenance and operation budgets of the project or experiment

The Collaboration and project management provide regular reports to the RRB on technical, managerial, financial and administrative matters.

# Experiment-Facility Interface Group

---

An Experiment-Facility Interface Group will be established to oversee and ensure the required coordination both during design, construction and the operational phases of neutrino program. This includes:

- Interface between the detector systems provided by the Collaboration and the technical infrastructure of LBNF
- Design and operation of the LBNF neutrino beamline.

The EFIG comprises Fermilab management, Collaboration Spokespeople, Technical and Resource Coordinators, and other members as deemed necessary to carry out the coordination function.

# Next Steps for international governance plan

---

- Goal is to deliver whitepaper to iIEB before Dec 21
- Afterwards iIEB, and then the new collaboration, can evolve the whitepaper in consultation with relevant stakeholders
- Eventually this turns into an international governance plan owned by the International Joint Oversight Group for LBNF



# Short Baseline Neutrinos (SBN) at Fermilab

---

**Recommendation 15: Select and perform in the short term a set of small-scale short-baseline experiments that can conclusively address experimental hints of physics beyond the three-neutrino paradigm. Some of these experiments should use liquid argon to advance the technology and build the international community for LBNF at Fermilab.**

## Strategy:

- Leverage from MicroBooNE experiment and existing Booster Neutrino Beamline
- Coherence with LBNF detector technology
- Building international community for LBNF requires a rapid timeline

# Short Baseline Neutrinos (SBN) at Fermilab

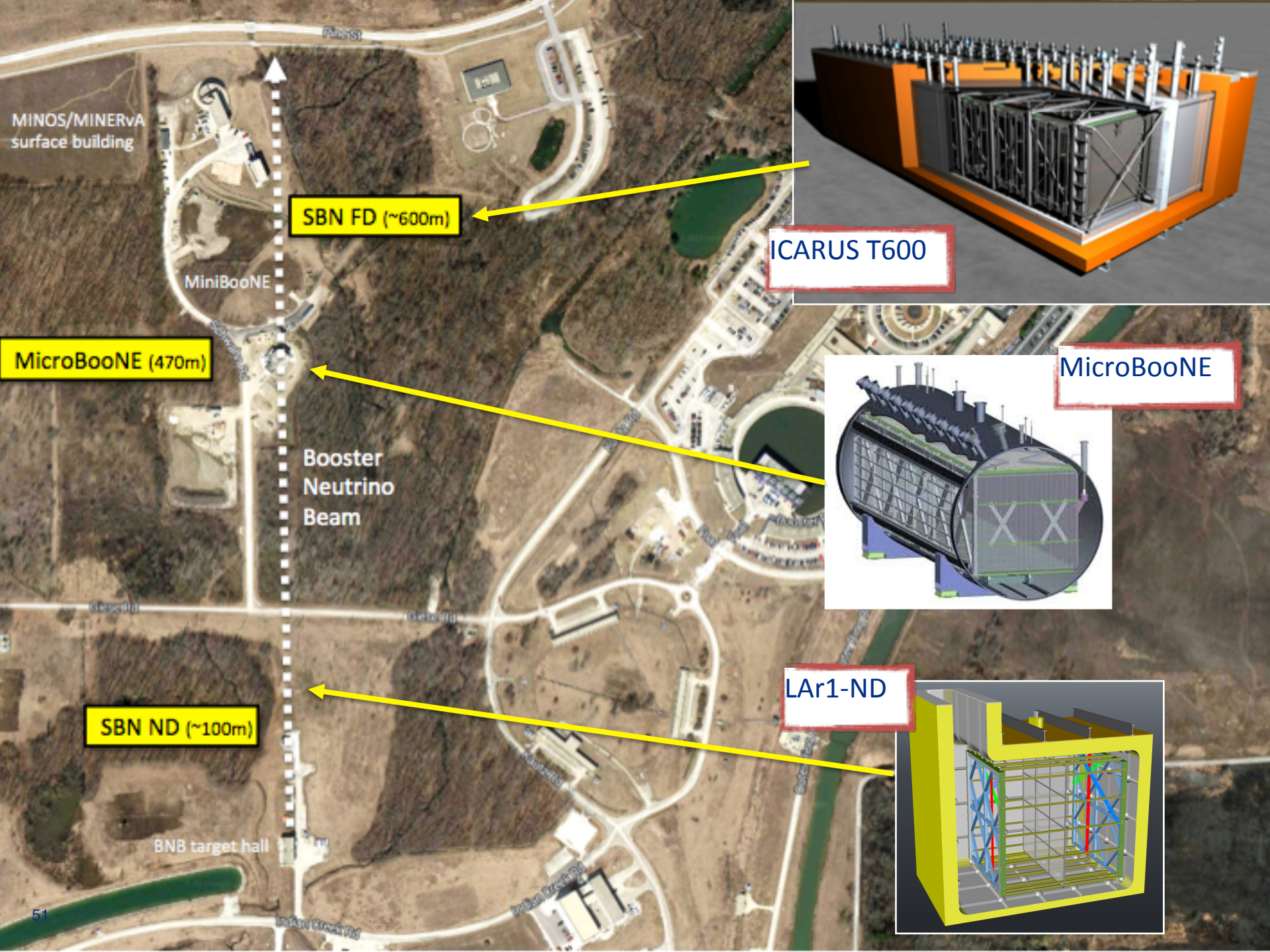
- MicroBooNE experiment begins data taking in a few months
- LAr1-ND recommended as near detector test experiment by Fermilab PAC, R&D towards LBNF detectors
- ICARUS detector coming to Fermilab in 2017 after refurbishing at CERN



Why is this man smiling?

First portion of  
ICARUS detector is  
already at CERN





MINOS/MINERvA surface building

SBN FD (~600m)

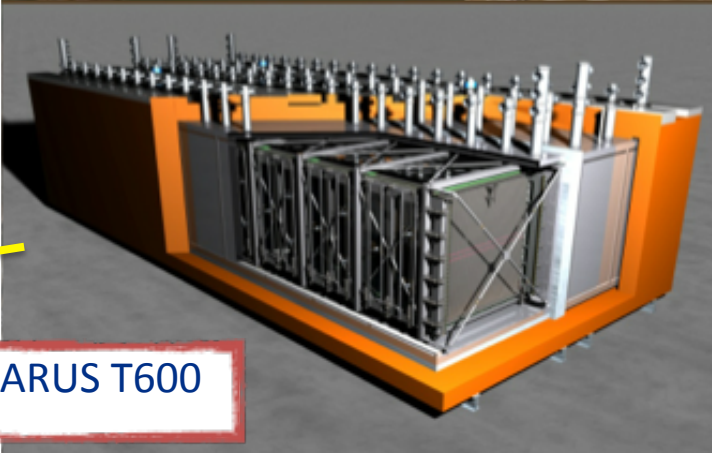
MiniBooNE

MicroBooNE (470m)

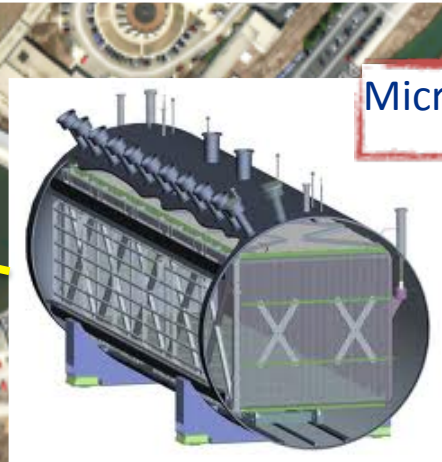
Booster Neutrino Beam

SBN ND (~100m)

BNB target hall

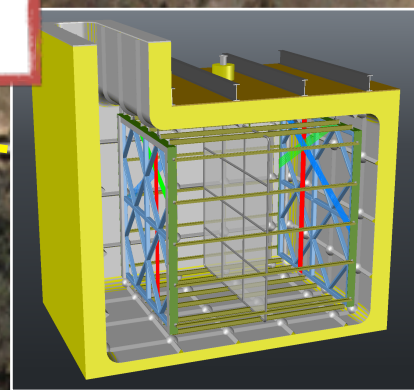


ICARUS T600



MicroBooNE

LAr1-ND



# Short Baseline Neutrinos (SBN) at Fermilab

---

- SBN proposal to be presented to Fermilab PAC in January
  - Joint proposal of MicroBooNE, ICARUS, and LAr1-ND
- International partners (so far): Italy, U.K., Switzerland, Poland, and CERN
- LAr1-ND leveraged by funding already awarded by NSF and UK STFC
- ICARUS refurbishing and delivery to Fermilab enabled by INFN and CERN
- Additional non-DOE resources are expected, including CERN contributions to infrastructure for LAr1-ND

# Outlook

---

- We are moving forward quickly on the new international neutrino program
- We are hopeful about securing the resources and partnerships needed to execute the whole P5 plan
- We are building for the future, at the same time as we serve our user community to do exciting discovery science
- The big looming challenge for Fermilab is stepping up our game on project management:
  - Still evolving the lab culture from an “operations lab” to a “projects lab”
  - Need to build confidence with DOE that we can execute on a project of the scale of LBNF