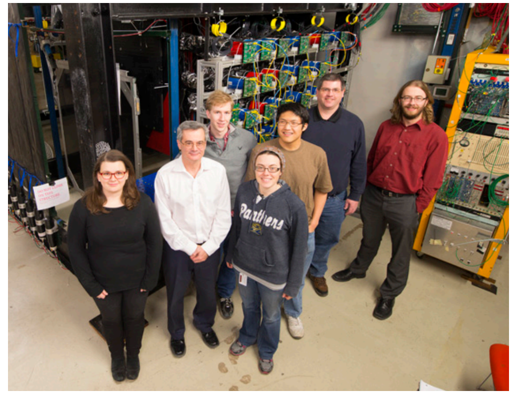
Status of Fermilab and Future Plans

Steve Brice

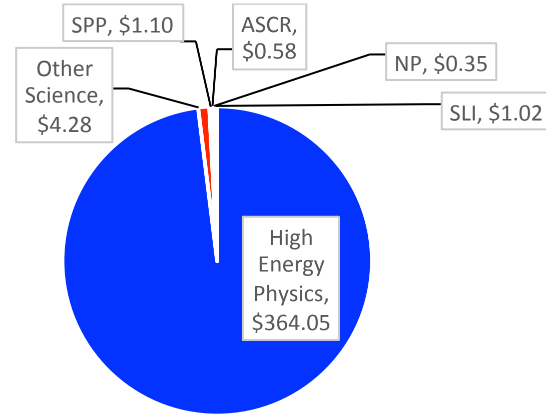
Oct. 31, 2015

Fermilab is America's particle physics & accelerator lab

6,800 acres
2.4 million GSF in buildings



1,760 FTEs
2,340 facility users



FY14 operating costs: $371.4M
FY14 DOE costs: $370.3M
FY14 SPP: $1.1M
Recovery Act costed from DOE sources: $1.9M

Our vision is to solve the mysteries of matter, energy, space, and time

We strive to:

- Lead the world in neutrino science with particle accelerators
- Lead the nation in the development of particle colliders and their use for scientific discovery
- Advance particle physics through measurements of the cosmos

Science strategy for the future

- Developing a flagship **neutrino science** program
- Driving **Large Hadron Collider science** and future upgrades
- Revealing **precision science**
- Advancing **accelerator science**
- Exploring **cosmic science**
- **Building** for science

Building for Discovery

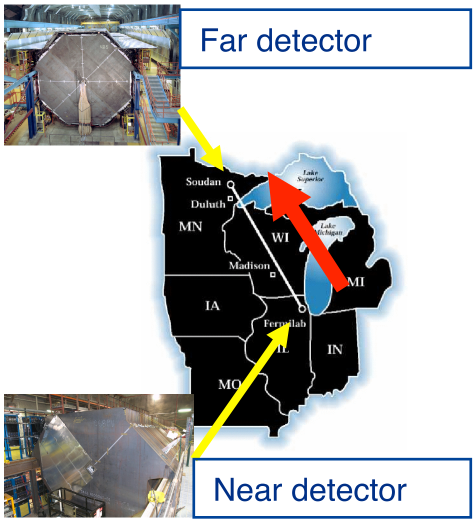
Strategic Plan for U.S. Particle Physics in the Global Context

Recent Progress

- DUNE/LBNF proceeding smoothly and on schedule
  - Organization in place for both DUNE and LBNF
  - In September CERN Council approved funding for neutrinos in Medium Term Plan, includes a cryostat for LBNF
  - CD1-refresh for DUNE/LBNF very successful, final DOE ESAAB sign-off set for Nov 5th, DOE TPC is $1.45 billion
- PIP-II CD-0
- IERC building ($85M) CD-0
- Accelerator complex delivered in FY15, coming out of a successful shutdown now
- g-2 and Mu2e baselined and SBN proceeding nicely
- Successful reviews of CMS phase 1 and phase 2 upgrades
- Exciting results from NOvA and DES with more to come

Current Neutrino Program

MINOS+



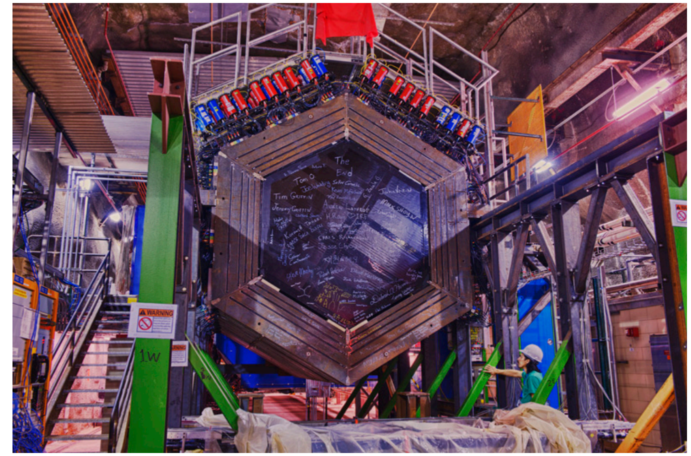
Since 2005, precise measurements of the atmospheric sector parameters, including the world's best value for delta_m^2 32.

MINOS+ running with higher energy NuMI beam for NOvA, precisely measuring shape of disappearance spectrum, extending sterile neutrino reach and exotic physics probe.

37 papers, expecting at least 9-12 more near-term covering a variety of standard and exotic neutrino physics topics.

75 theses with 10 currently in preparation.

MINERvA



Past Publications:

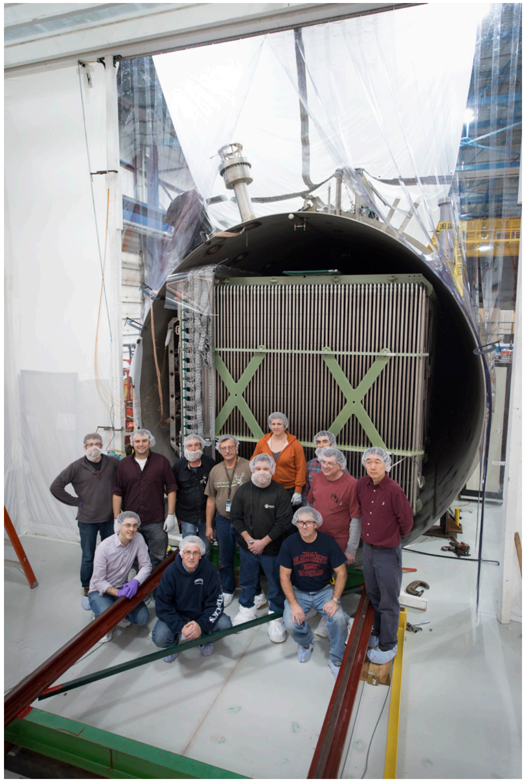
- Physics: 7 published (4PRL's, 2PRD's, 1 PLB), 1 on arXiv about to be submitted to PRL (nu_e CCQE Cross Section).
- Technical: 4 NIM papers published

Future Publications:

- Physics: another 12 PRL+PRD's to come in Low Energy data set + ~20 from Medium Energy
- Technical: Expect another NIM on New Test Beam Data

Students
15 PhD's awarded so far
Current Students: 20 PhD students now, 7 of them to graduate by Summer 2016

MicroBooNE



TPC insertion Dec 2013

Cryostat Insertion June 2014

First beam delivered last week

NOvA

Project completed Sept. 2014

- DOE Secretary's Award of Excellence

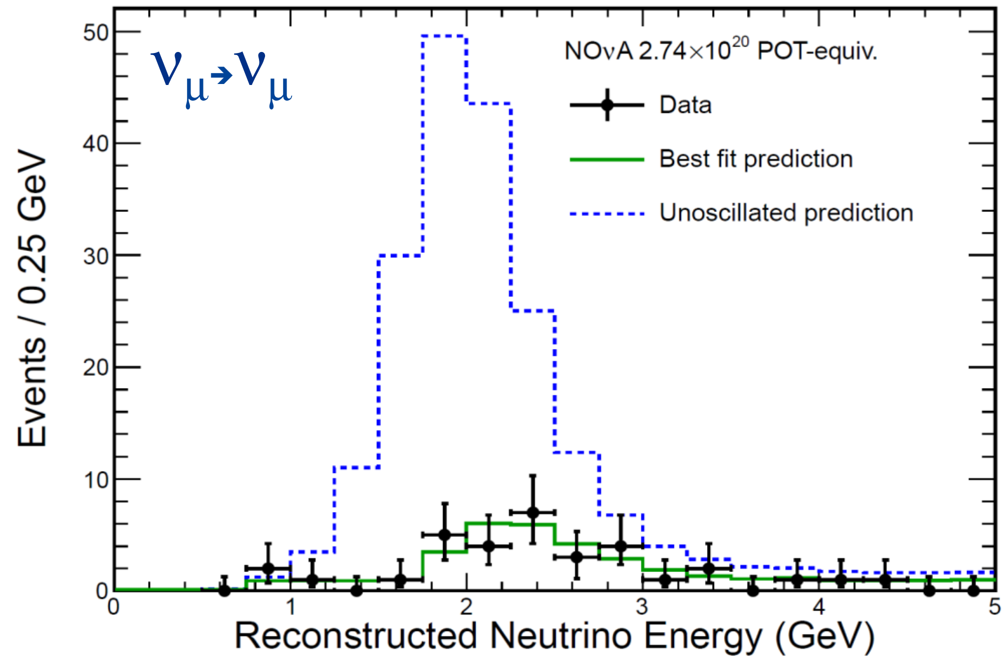
Operations

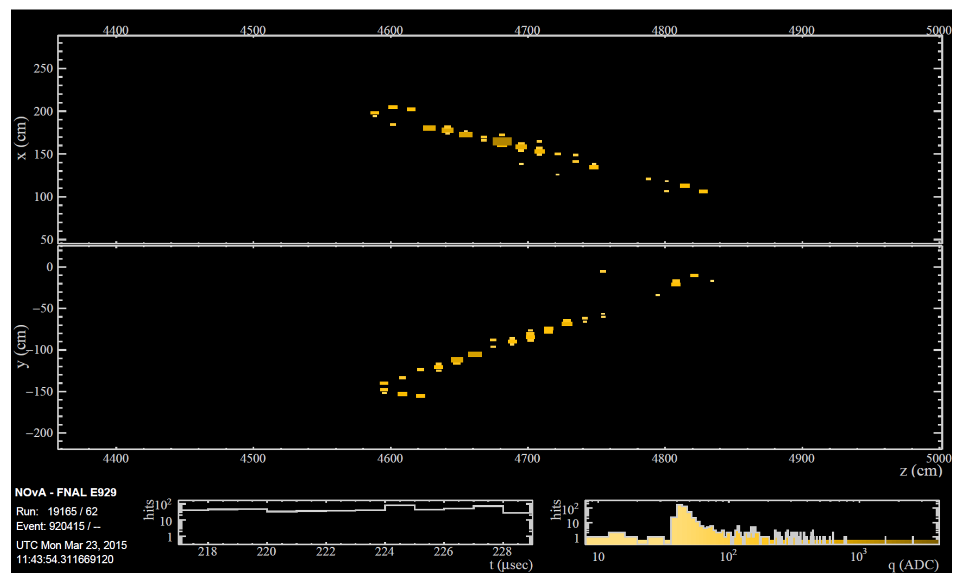
- Routine 420 kW NuMI running in spring 2015. 520 kW world record in June. On track for 700 kW in 2016
- Detector uptimes > 95%

First Oscillation Results Aug. 2015

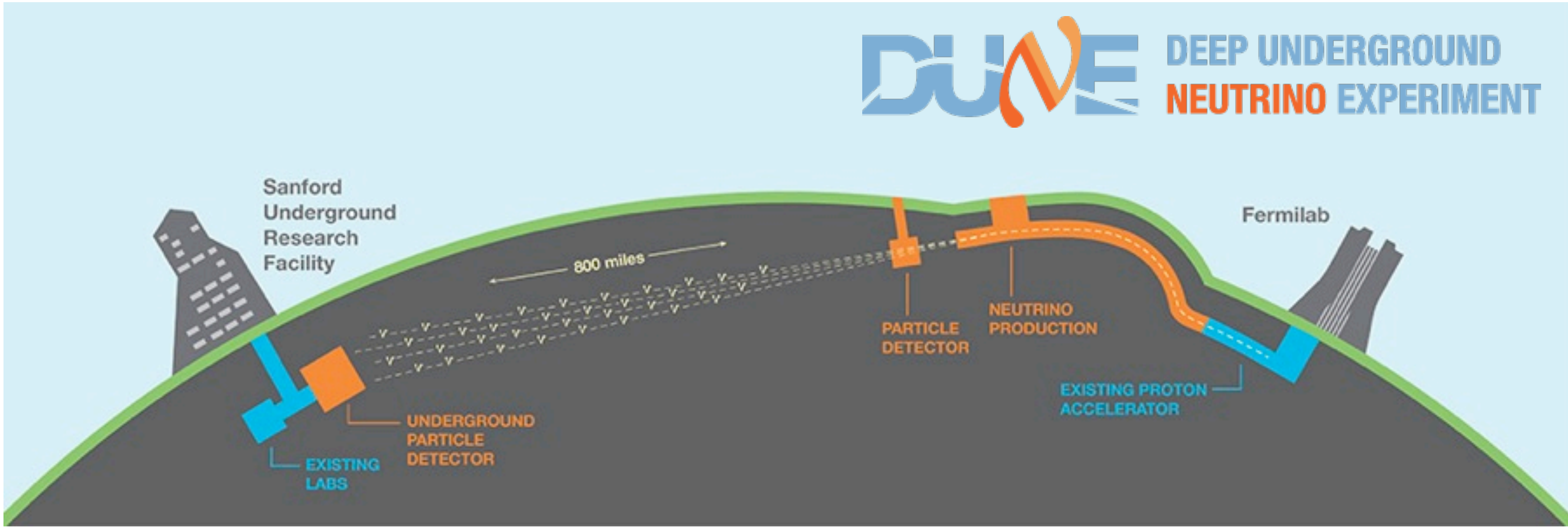
- ν_μ Disappearance: Compelling initial measurement, consistent results with previous experiments
- ν_e Appearance: 6 events observed over a background of 1 (3.3 s)
- Slight favoring of large CP violating effect and normal mass ordering

NOνA Preliminary





DUNE

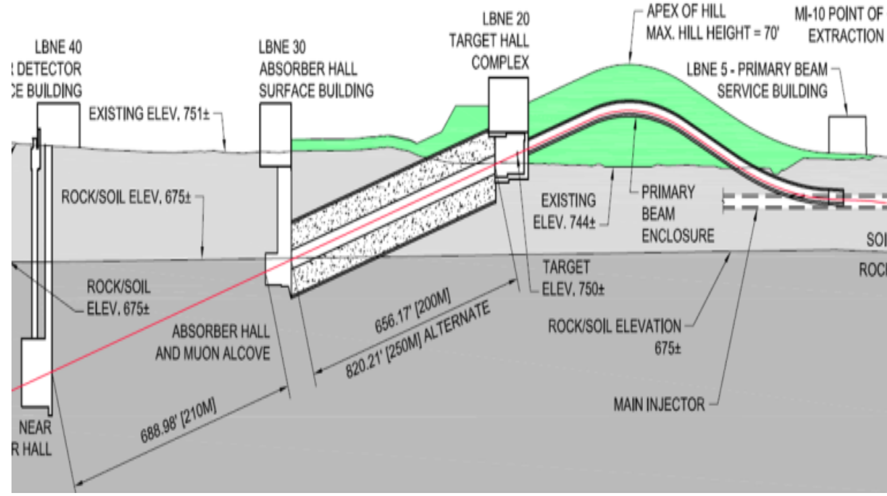


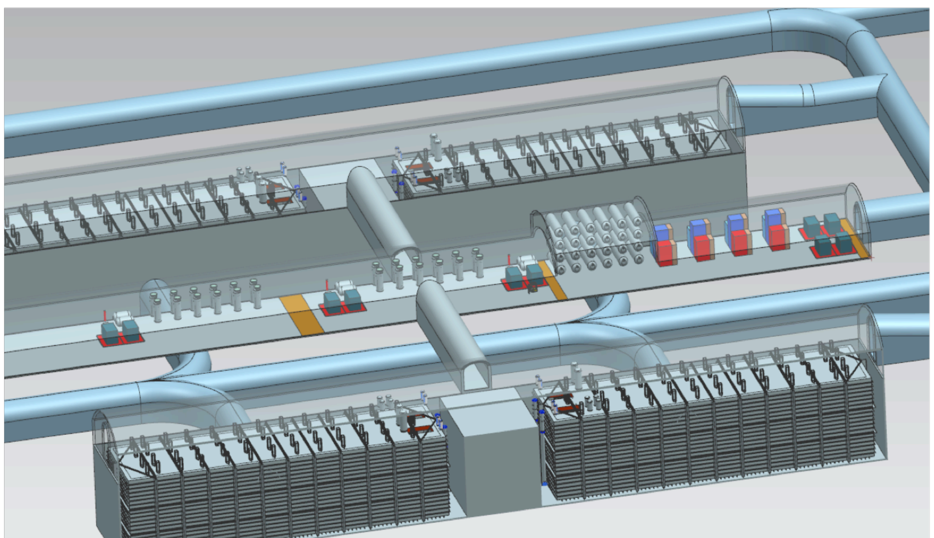
Fermilab's proposed flagship experiment will be the "first truly international mega-science project on U.S. soil," according to Pat Dehmer, deputy director of the DOE Office of Science. It will be the game-changing experiment for neutrino research.

World-leading long-baseline program

Lab objectives:

- Cavern construction begins 2017 at Sanford Underground Research Facility
- Installation of 1st 10-kiloton detector module underground completed 2024
- Additional 30 kilotons of space excavated
- Neutrino beamline completed 2025





Layout of underground cavern housing the DUNE liquid argon far detectors and associated cryogenics system.

Recent achievements:

- DUNE Collaboration formed
- Cavern excavation and detectors reconfigured to be modular
- Proposal for single-phase full-scale prototype approved by CERN SPS and PS experiments Committee (SPSC)

LBNF/DUNE: International in the DOE context

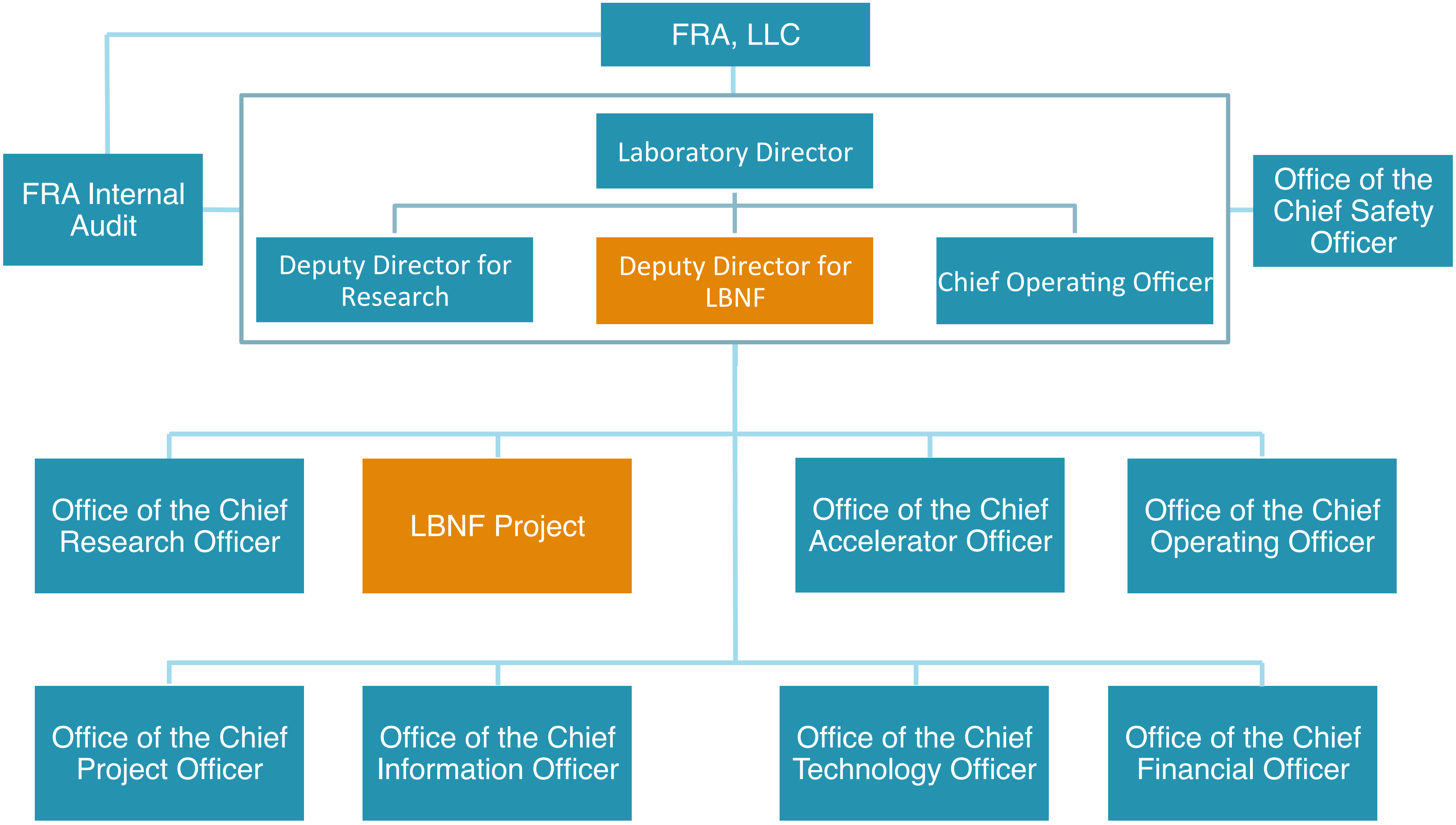
- Start from the beginning designing what you wish to accomplish scientifically with international colleagues
- Start with funding agencies talking to one another and collectively following the process from the beginning
- Funding agencies and scientists define the governance structure
- Discuss the cost sharing with the major partners from the beginning
- Partners bring something unique and critical technology not present at host lab (e.g. U.S. high-field magnets to high-luminosity LHC or liquid-argon detector technology from Italy to the U.S.)

DUNE Collaboration includes 776 members from 144 institutes and 26 countries as of June 1st, up from 503 members from 23 countries signing the LOI in January.

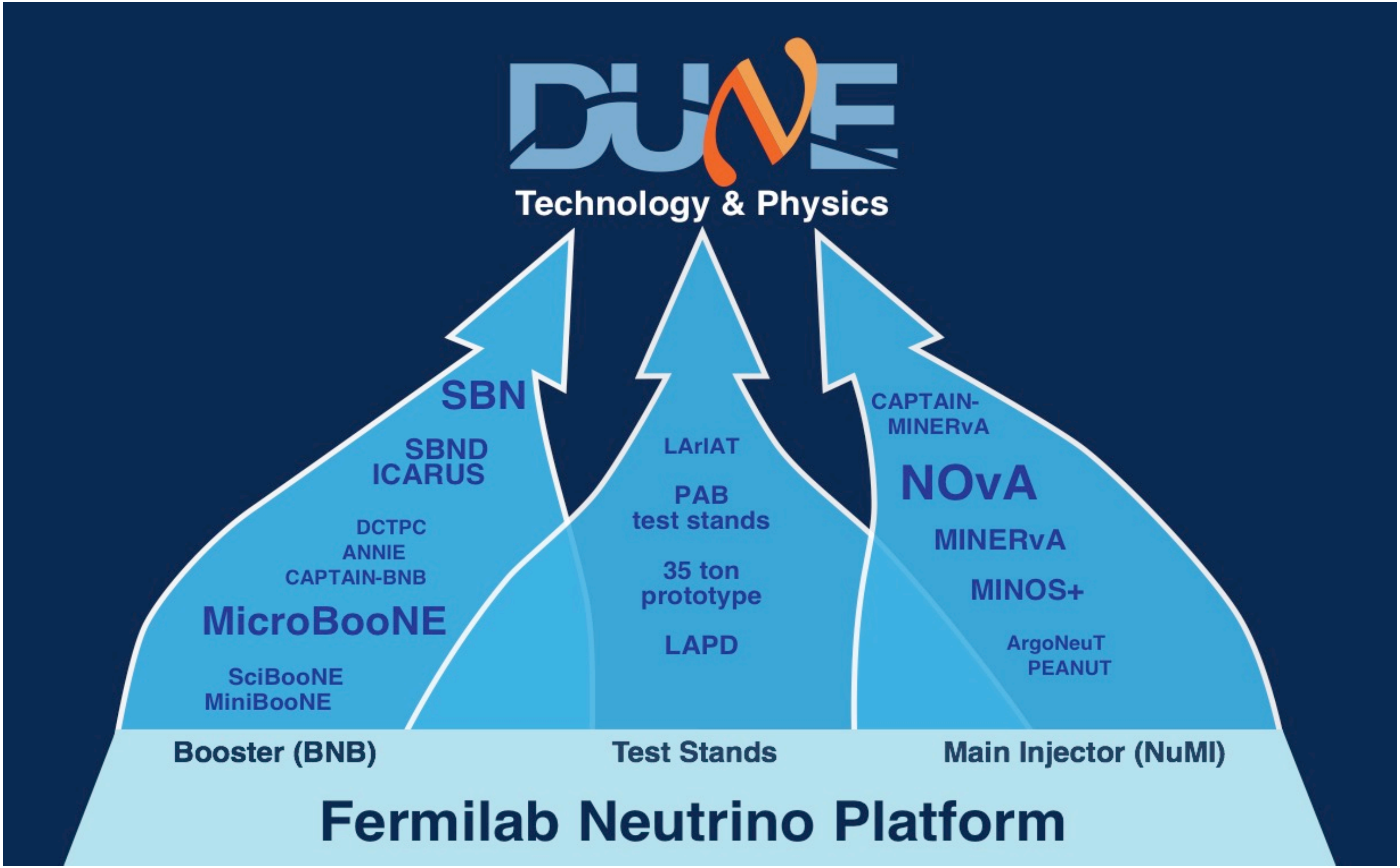
A global experiment to understand neutrinos

The DUNE collaboration includes more than 780 scientists from 145 laboratories and universities in 26 countries.

Adapting the organization



All roads lead to DUNE



Fermilab Neutrino Platform

Accelerator Division

Neutrino Beams : NuMI, BNB

Charged Particle Test beams

High Power Targets and Horns

Neutrino Division

Detector R&D test stands

Detector Halls : NuMI, SciBooNE, LArTF

Neutrino Beam Group

Collaboration with Neutrino Theory

ND Operations Support

Neutrino Physics Center

ROC West

Scientific Computing Division

GENIE

ART

Geant4

ARTDAQ

LArSOFT

NuTools

Facility Engineering Support Services

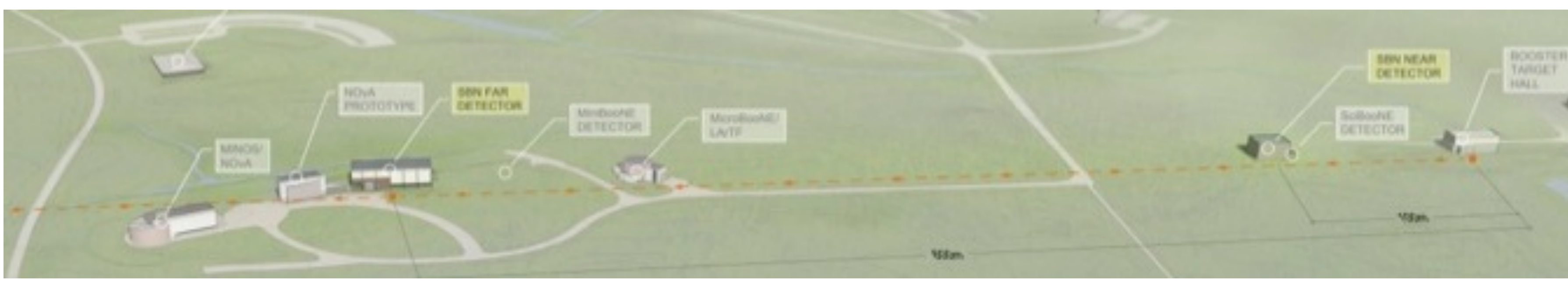
Particle Physics Division

Core Computing Division

Technical Division

The road to DUNE… across the ocean

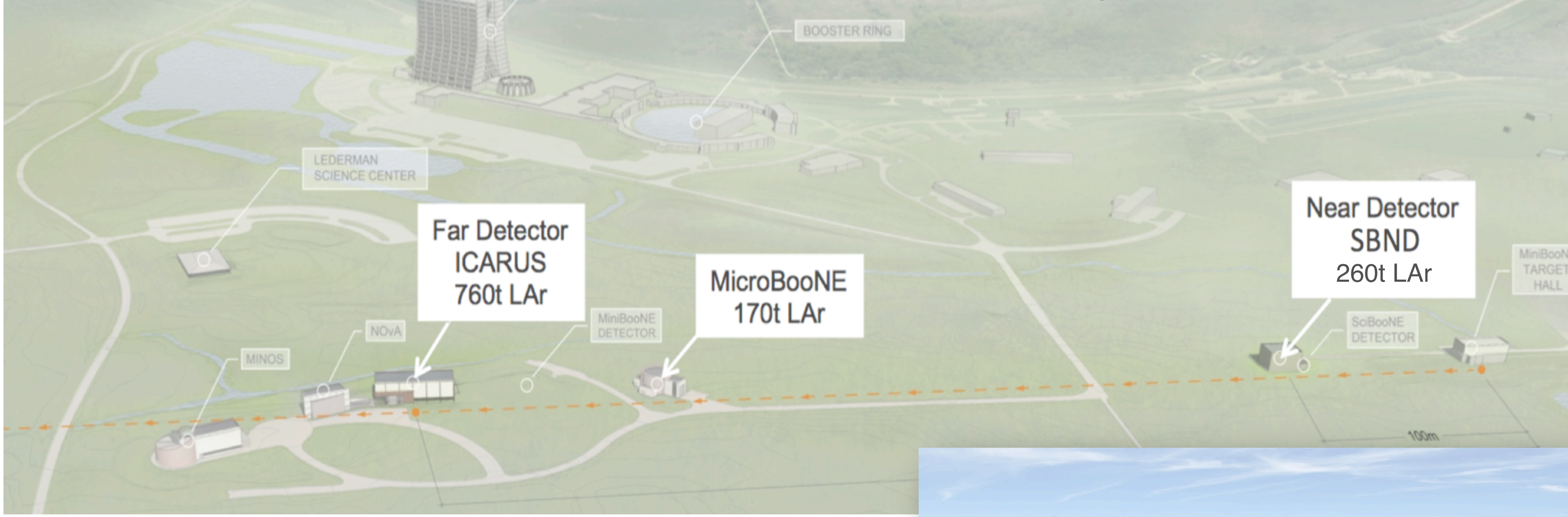
The technology that will power DUNE has been used to build other detectors. The world's largest of these, ICARUS, will come to Fermilab in 2017. It will join MicroBooNE and another new detector to study neutrinos here on the Fermilab campus.



SBN - Short-baseline neutrino program

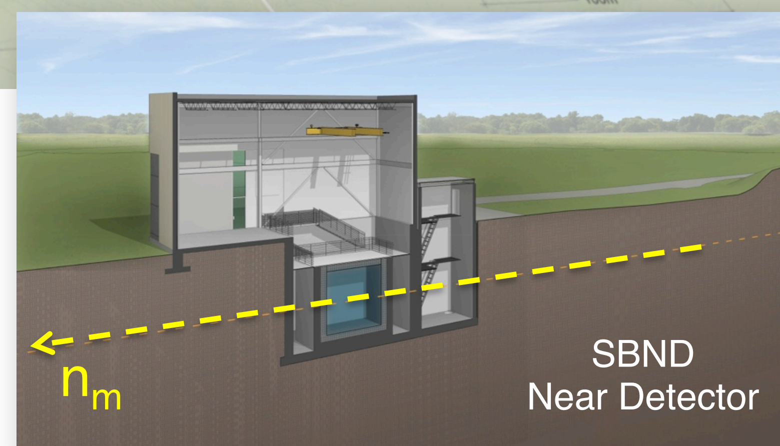
Primary challenge:

Three detectors with one mission: Are there more than 3 types of neutrinos?



Lab objectives:

- MicroBooNE taking data in 2015
- SBND built and taking data by 2018
- Refurbished ICARUS detector at Fermilab and taking data by 2018



Short-baseline neutrino program

Science goals:

- Understand the MiniBooNE excess and measure neutrino cross sections in argon
- Launch a definitive search for sterile neutrinos using multiple LAr TPCs
- Test and improve DUNE prototype design

SBN recent achievements:

- MicroBooNE now taking neutrino data
- SBN Director's Review mid-Dec 2015
- ICARUS detector moved to CERN and refurbishment started January 2015
- U.S. groups joined ICARUS collaboration

Far detector building construction

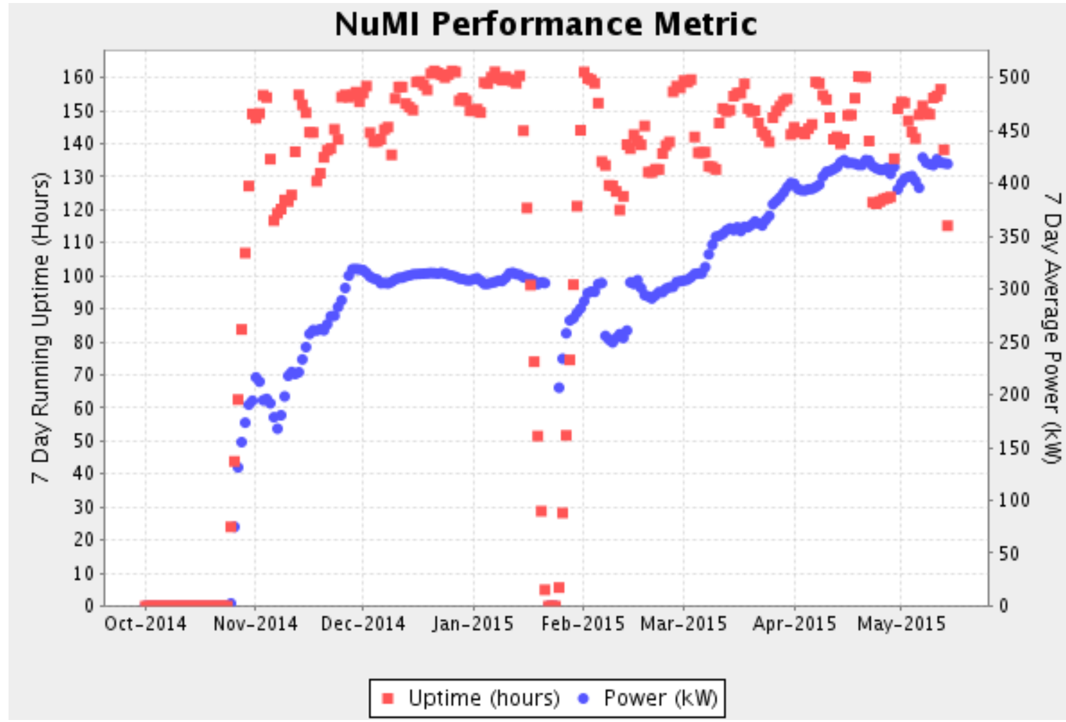
First T300 in cleanroom at CERN

The road to DUNE… accelerated

Fermilab's Main Injector generates the most powerful neutrino beam in the world, and will only get better in the coming years. Fermilab currently operates two neutrino beams at different energies, making us unique among laboratories studying this particle.

NuMI Beam Power

- Running at average beam power levels of ~ 420kW since April 2015
- Plan to run at 575kW starting in Dec 2015
- Plan to demonstrate 700kW running in March 2016



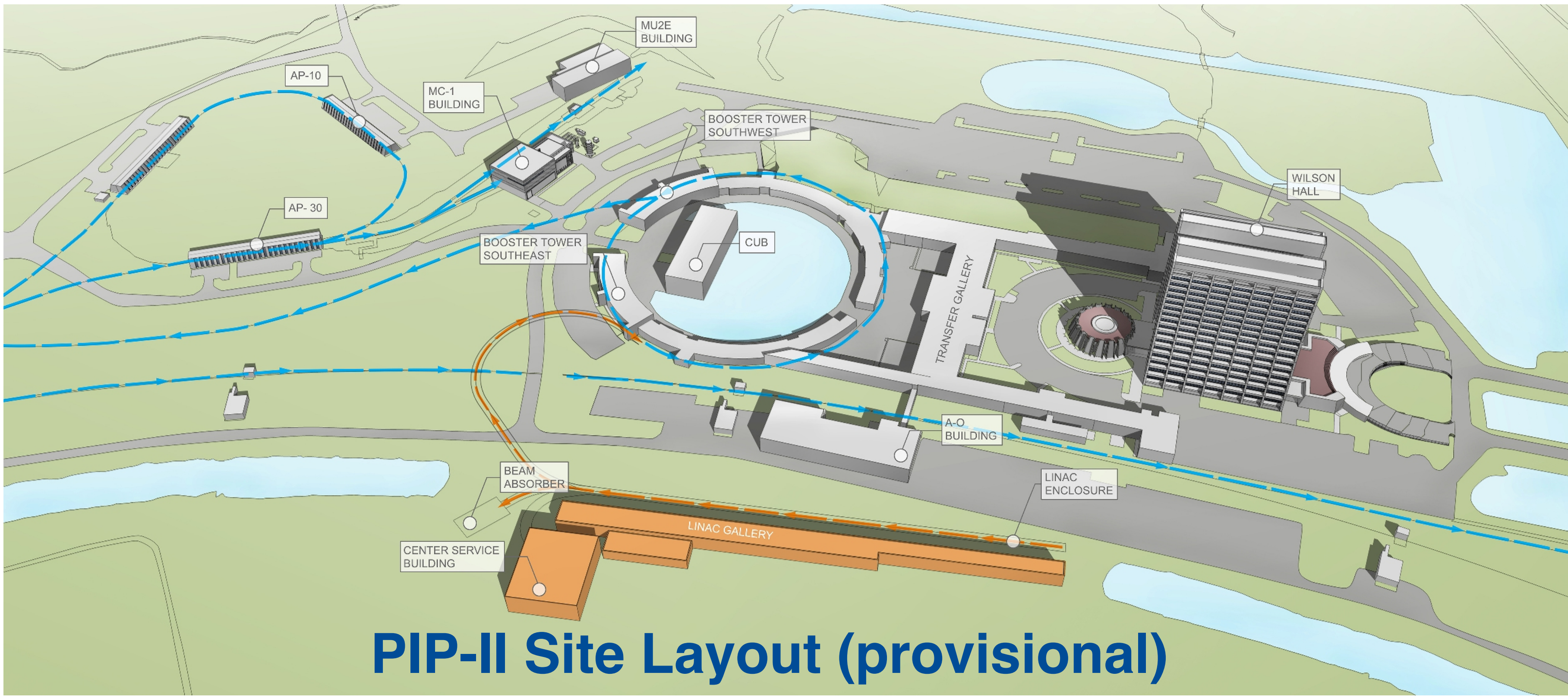
- Beam losses will probably preclude steady state 700kW running until MI collimators are installed in the summer 2016 shutdown

Fermilab

Highest power beams for neutrinos

Lab objectives:

- PIP (700 kW), Booster (15 Hz) → fully exploit the science of NOvA and SBN
- PIP-II (1.2 MW), PIP-III (2.4 MW) → fully exploit the science of DUNE



Extending the scientific reach of existing accelerator facilities and enabling PIP-II

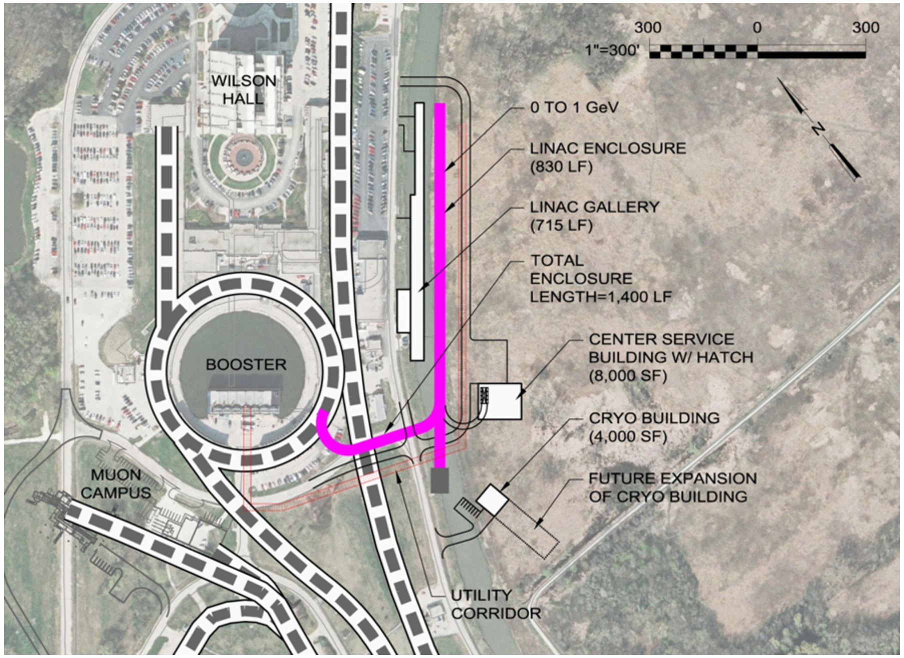
PIP-II science goal:
Provide >1 MW of beam power at LBNF startup; provide platform for future high-power/high-duty-factor capability (e.g. Mu2e up to 100 kW)

PIP-II technical challenges:
- High-performance beam source
- High-efficiency SRF acceleration

Recent achievements:
- Low-energy source and transport beam line commissioned
- RFQ delivery and installation
- SRF program advanced

Operations start: FY2024

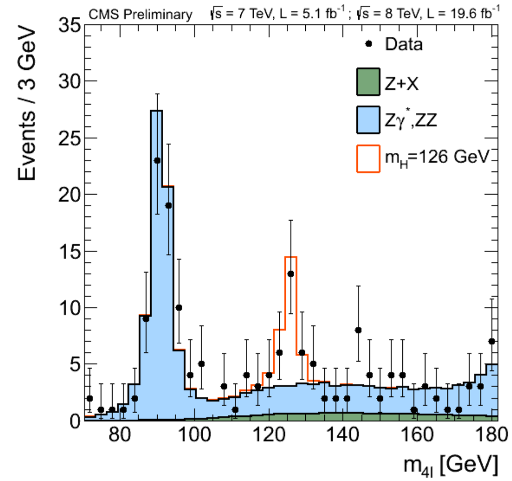
PIP-II Site Layout (provisional)

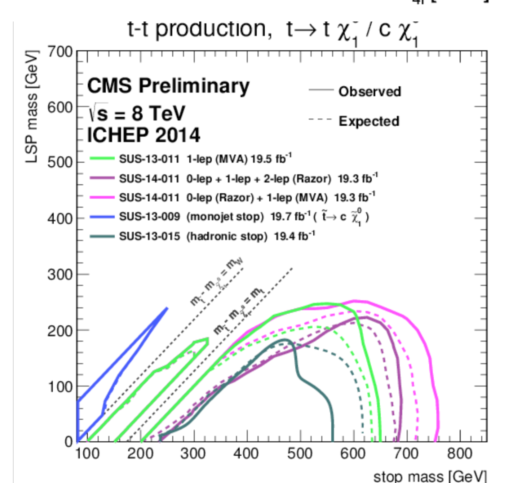


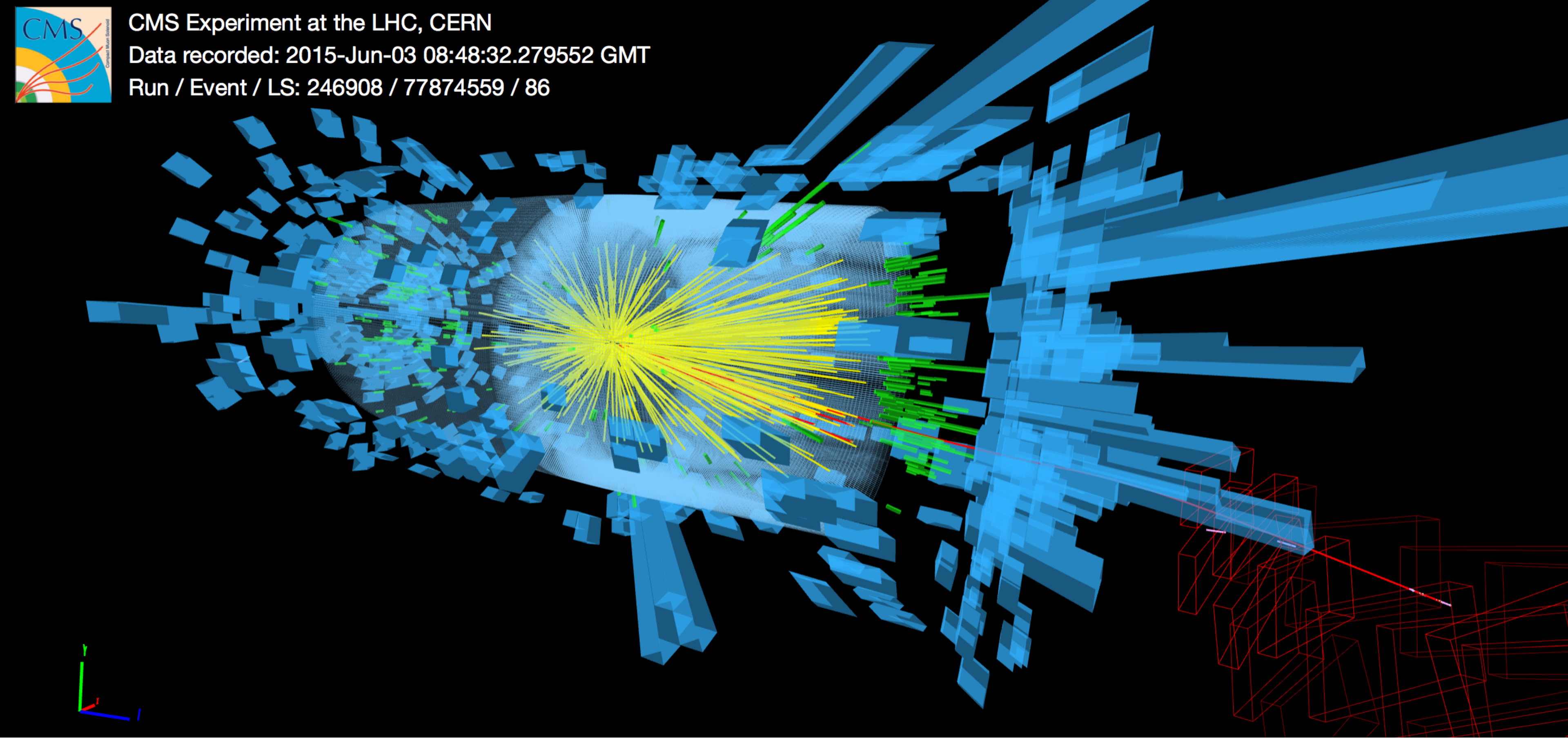
Partnerships
DOE labs: ANL, LBNL, ORNL
U.S. universities: Cornell, NIU
International: multiple laboratories

CMS

- Largest US group on CMS and second largest group overall
  - currently ~60 CMS authors (+ 4 emeritus), including 15 postdocs
  - Total effort (including professionals) is >100 FTE
- Fermilab personnel are currently active in:
  - Analysis of CMS data: Higgs properties, SUSY searches, SM measurements
  - Construction of Phase 1 Upgrades and R&D for HL-LHC: Hadron Calorimeter, Forward Pixels, Outer Tracker, Trigger
  - Computing - Host of US Tier-1 (largest of all T1s)
  - Core, reconstruction, and simulation software
- Host lab for CMS in the US
  - Manage Operations Program and Upgrade Projects
  - Host LHC Physics Center and Remote Operations Center for university users







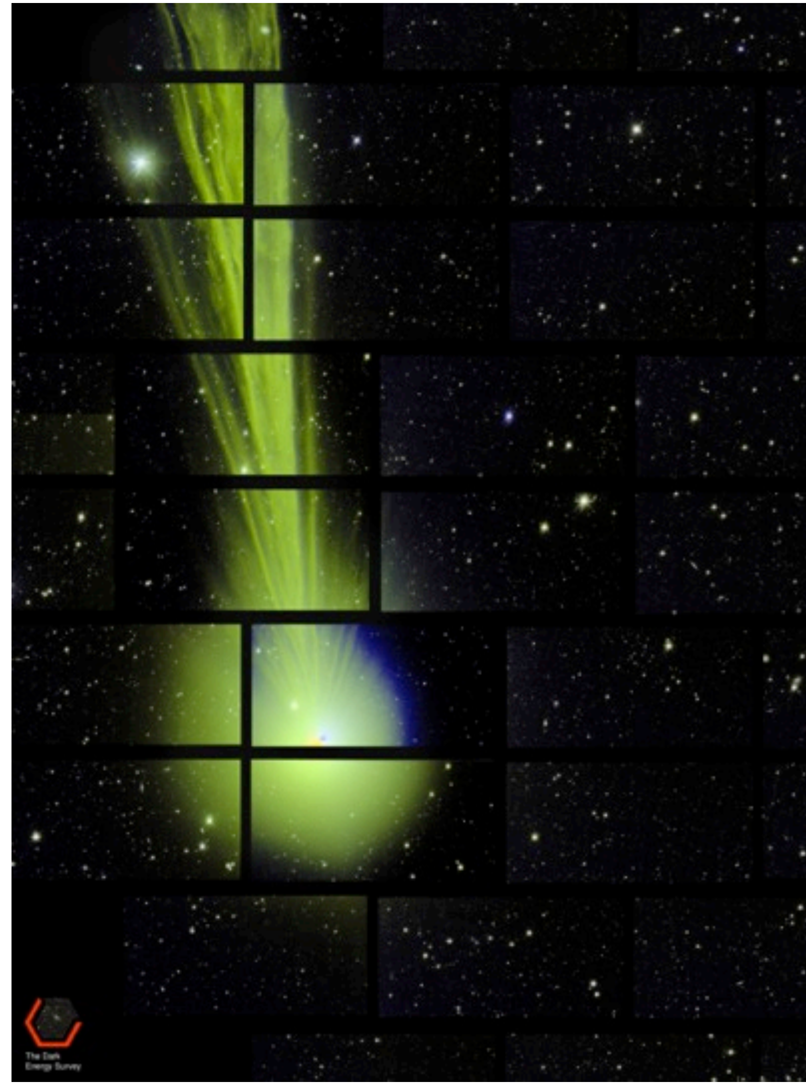
In 10 years Fermilab will continue to be the leading U.S. center for CMS, and the second leading center in the world after our partner CERN.

Lab Goals (5 years)

- Maximizing science from LHC Runs 2 and 3
- Completing CMS phase 1 and establishing phase 2 upgrade projects
- Completing LARP and establishing the high-luminosity LHC upgrade project
- Maintaining technical expertise and facilities to support the LHC program
- Continuing R&D and physics studies for future colliders

DES and Cosmic Acceleration

The Dark Energy Survey uses one of the world's best digital cameras, mounted on a telescope in Chile. The third year of five has just begun, and the Survey has found 17 new dwarf galaxies, caught Comet Lovejoy in a stunning photobomb, and is on the way to understanding more about dark matter and dark energy, which make up most of our universe.

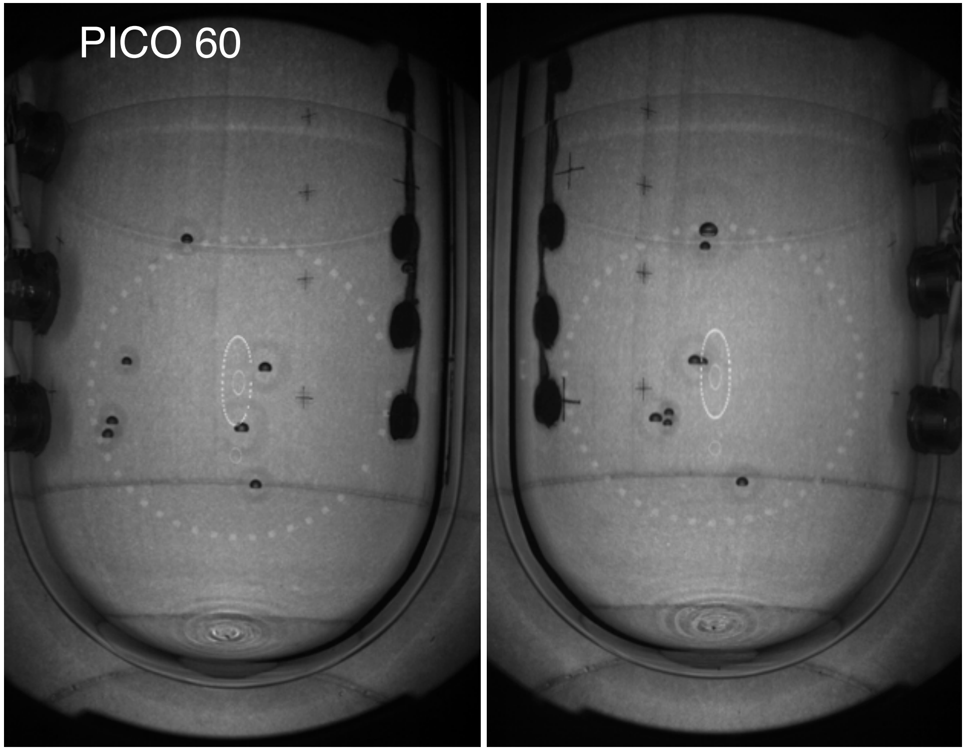


Direct searches for particle dark matter

Primary challenge:
Identify the new physics of dark matter

Lab objectives:

- Support Generation 1 (G1) dark matter operations through 2017, and improve on world-leading results
- Build SuperCDMS SNOLAB with commissioning by 2019
- Develop tunable high-Q RF cavities for ADMX G2 high-frequency axion search
- Provide process control, cryogenic, and scientific expertise to enable LZ to take data in 2019



Recent achievements:

- G1 experiments have released world-class results in the past year, including world-leading limits on spin-dependent and low-mass dark matter

Muon program: Mu2e

Science goal:

- Improve sensitivity to $\mu^- N \rightarrow e^- N$ by factor of 10,000
- Achieve discovery sensitivity to new physics up to an effective mass scale of $L_{NP} \sim 10^4$ TeV/c^2

Lab objectives:

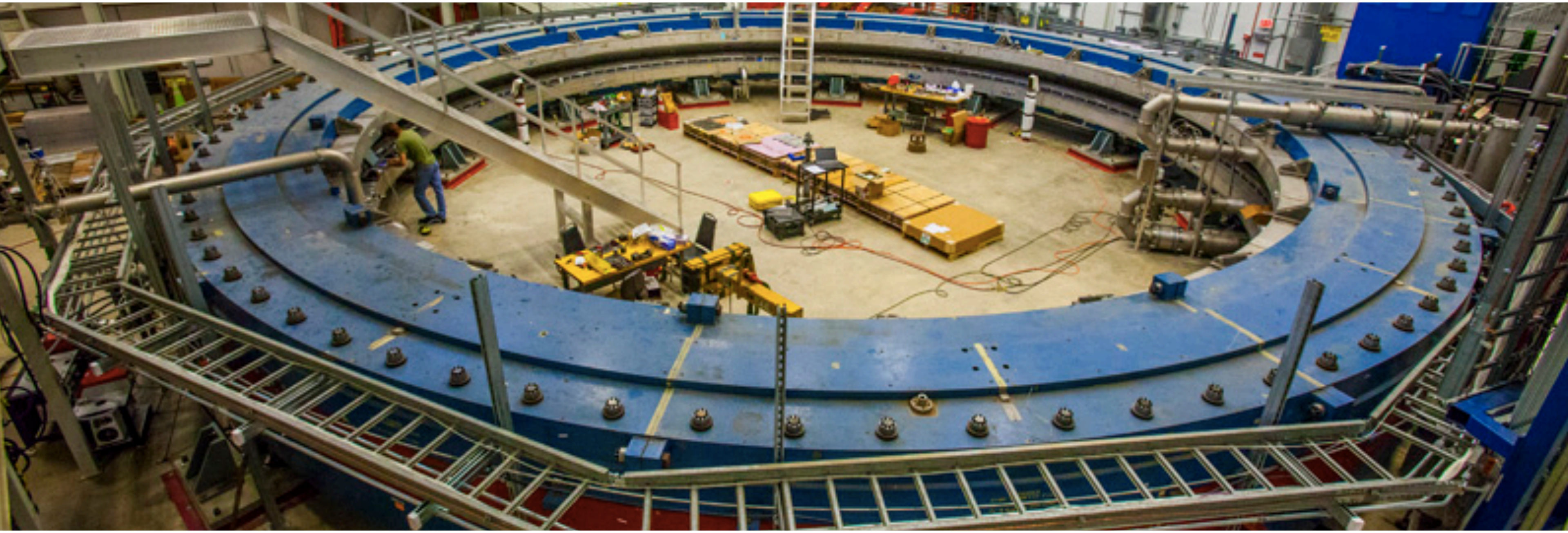
- Complete construction project on time and under budget
- Take SINDRUM-II size data set in 2020, full data set by 2023

Recent achievements:

- Achieved CD-2/3b March, 2015
- Successful construction of prototypes for many systems

Muon program: Muon g-2

Science goal: Explore the present 3σ discrepancy with > 5σ discovery potential



Lab objectives:

- Complete the construction project on time and under budget
- Collect Brookhaven-size data set by end of 2017, 20x BNL data set by end of 2019

Recent achievements:

- Storage ring magnet reassembled, cool, and at full current.

Explore scientific limits to gradients and quality factors for future SRF accelerators

Science goal:

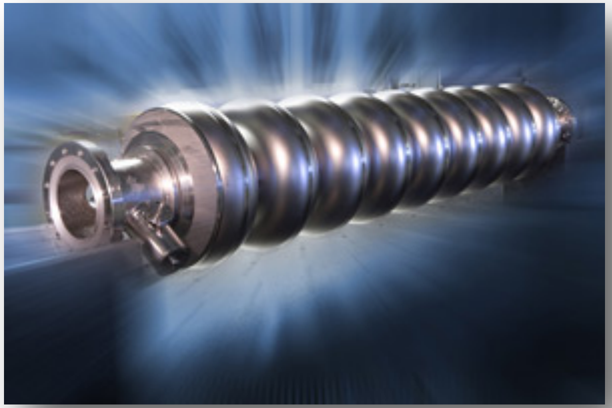
Develop an understanding of the scientific limits to gradients and efficiency (Q_0) for SRF accelerators

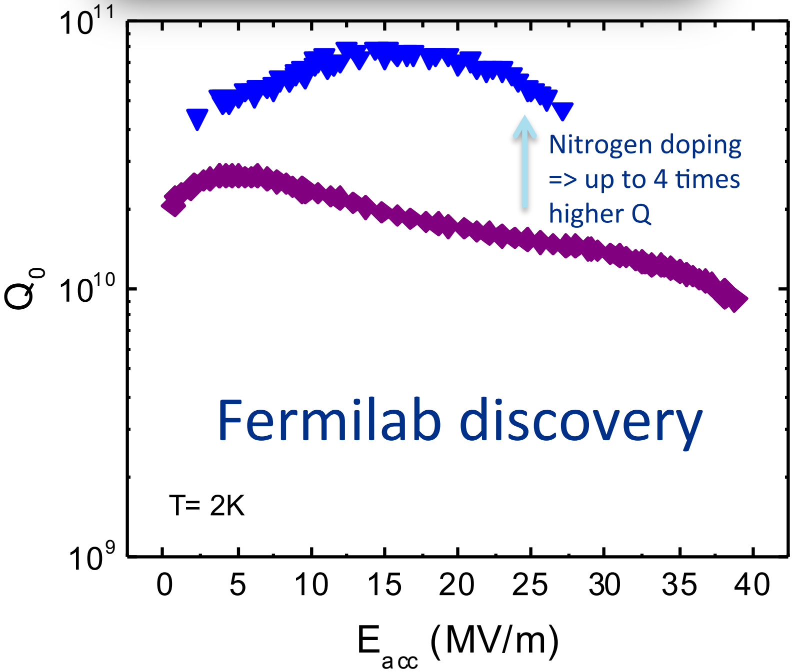
Technical challenges:

- Understand origin of nitrogen doping effect
- Uncover physical mechanism underlying efficient magnetic flux expulsion by thermal gradients
- Understand origin of localized quench and explore superheating field improvement in niobium and new materials such as niobium-tin (Nb_3Sn)

Recent achievements:

- All-time record for quality factors in SRF cavities (Q > 2e11 up to 20MV/m) achieved by nitrogen doping and efficient magnetic flux expulsion
- Discovered performance-determining mechanism caused by non-superconducting nanohydrides





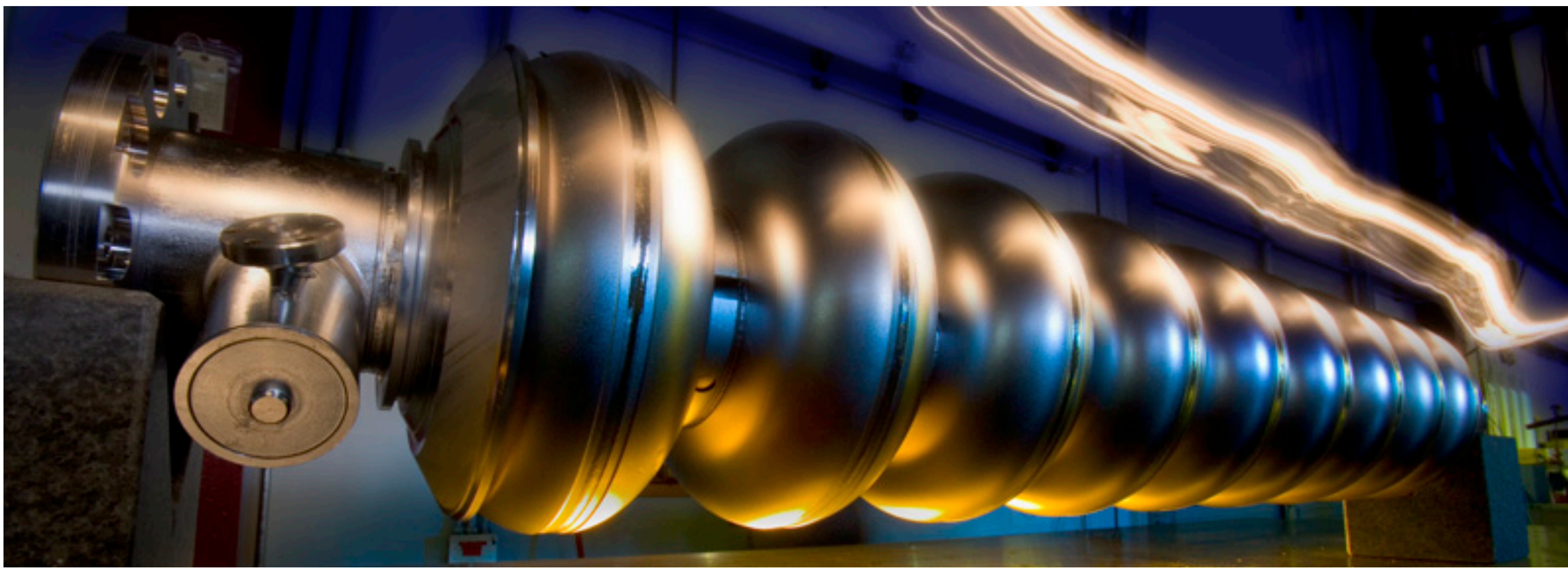
Accelerating industry

NOW

- Hardening ceramic surfaces
- Changing colors in gemstones
- Sterilizing medical instruments
- Treating cancer
- Scanning cargo

FUTURE

- Improving wastewater treatment
- Extending highway lifetime
- Making food safer
- Converting flue gases into fertilizer
- Recovering more natural gas



In 10 years Fermilab and its partner institutions will have made Illinois a world center for accelerator science.

Lab Goals (5 years)

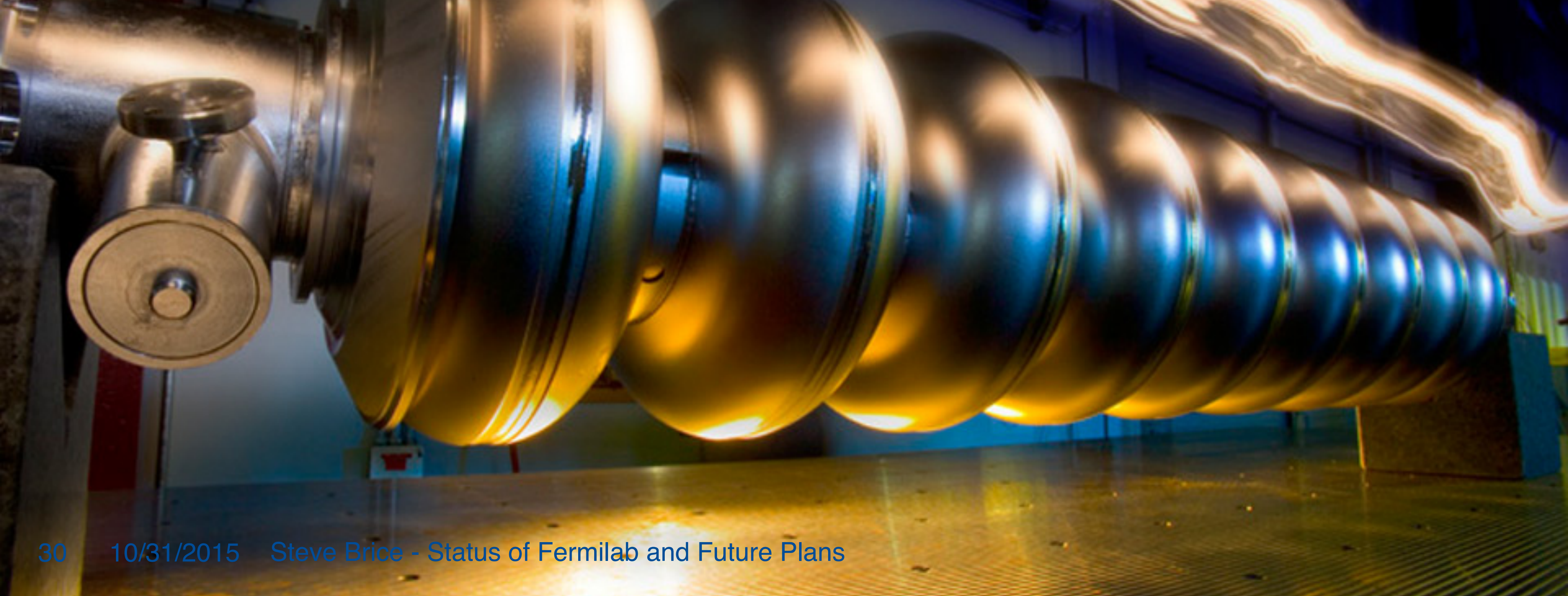
A1) Extending the scientific reach of existing accelerator facilities and enabling PIP-II

A2) Exploring scientific limits to gradients & quality factors for future SRF accelerators

A3) Launching a test facility to enable transformative accelerator science

A4) Establish Fermilab as an essential contributor to future large accelerators

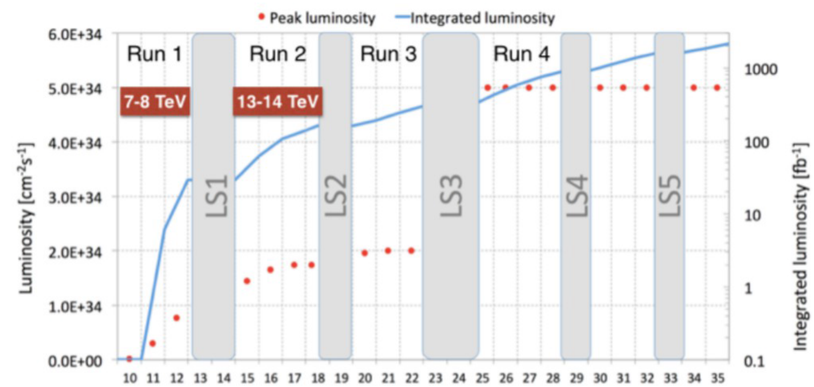
A5) Supporting U.S. industrial competitiveness



Scientific computing

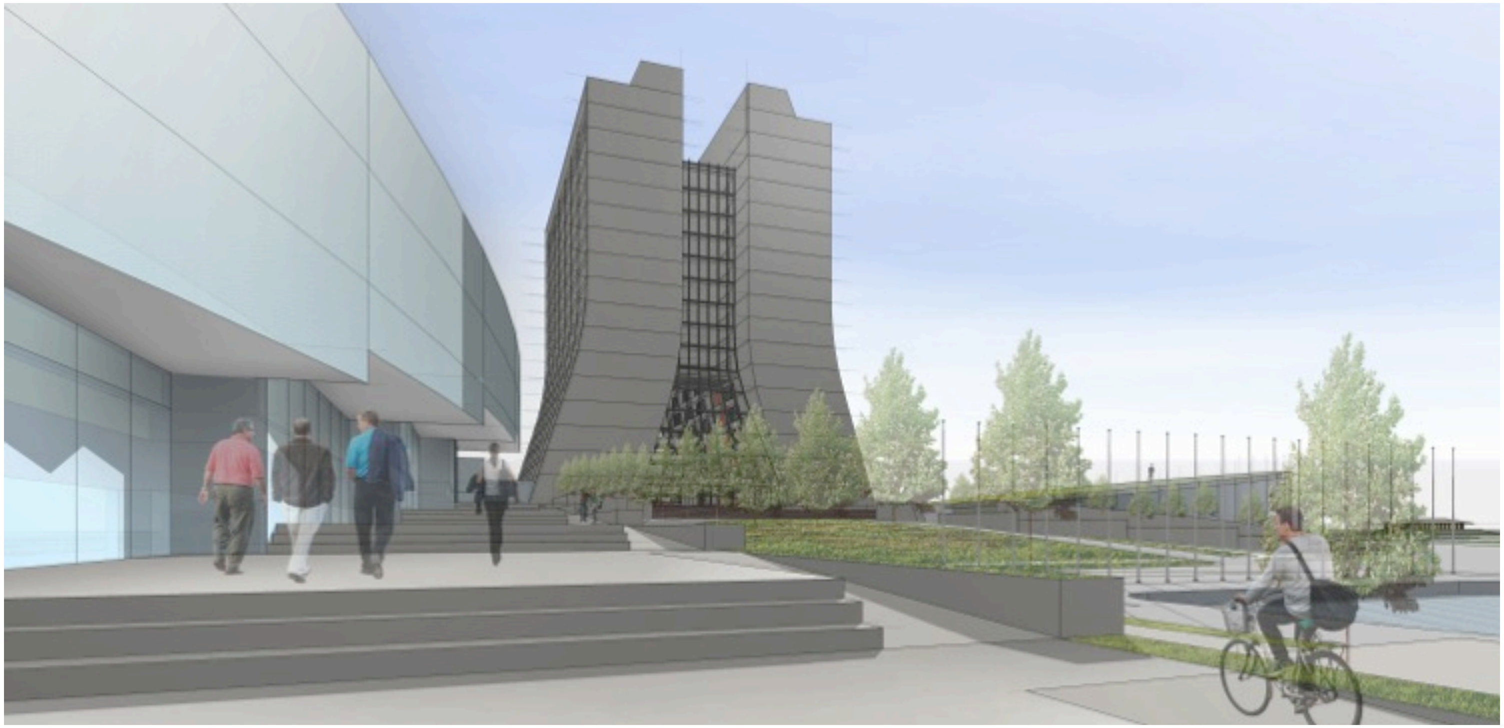
- Evolving science programs (such as the LHC program) require higher precision, higher data rates, and increased data complexity
- Fermilab is working in partnership with HEP and ASCR institutions to evolve software and computing facilities to:
  - Take advantage of new architectures, high performance computing, and cloud computing resources
  - Improve performance, efficiency, operations, and cost effectiveness
- The lab has been successful in high-impact areas such as analysis frameworks and simulation tools, and is developing a partnership with ASCR on a major computing facilities initiative

LHC program evolution will increase computing capacity needs to 10x – 30x current needs



Fermilab

A new-look Fermilab for a new era



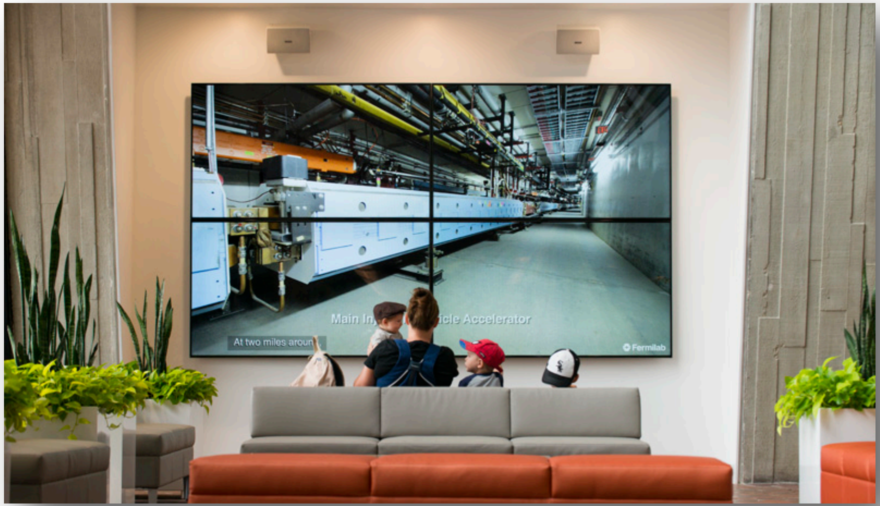
We need robust infrastructure to support our future flagship program. Modernization of utilities is already underway, and first-stage approval has been received for a new building that will help us create an international campus for scientists from around the world.

ROC-West

Control room for all the lab's onsite experiments
(ROC-East is CMS control room)

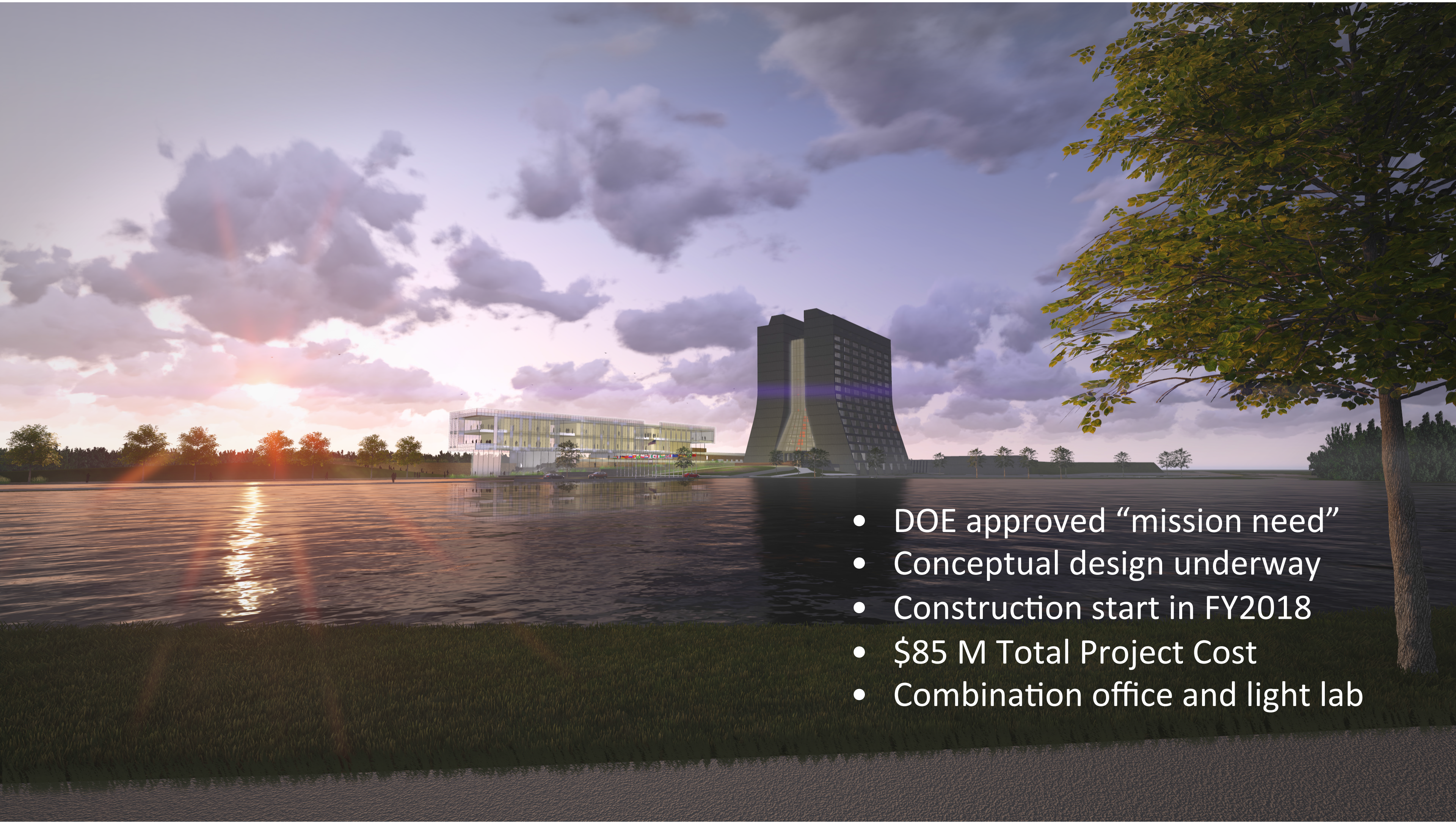
In operation for a year and has become a major feature of the lab

Reinvigorating the Wilson Hall Atrium



An attractive space to hang out and collaborate

Integrated Engineering Research Center (IERC)

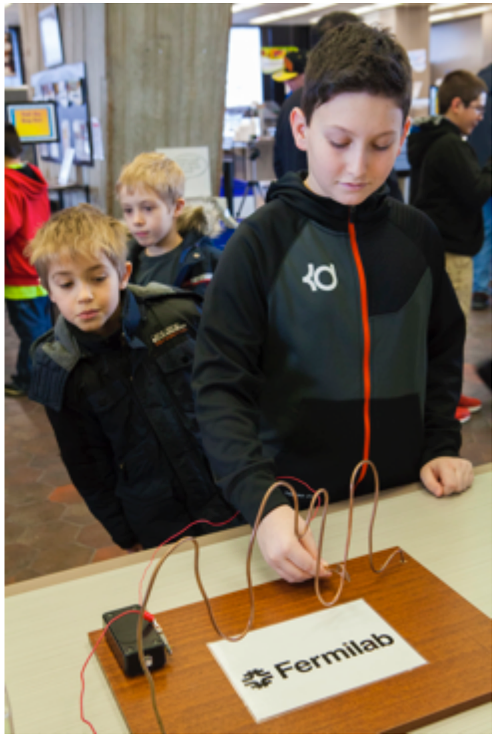


- DOE approved "mission need"
- Conceptual design underway
- Construction start in FY2018
- $85 M Total Project Cost
- Combination office and light lab

Fermilab Hostel: We need one; looking at options

Fermilab

Science that matters to our kids



Fermilab partners with educators and parents to introduce youth to the world of science. Last year 17,000 students came to Fermilab, and we reached 26,000 more in their classrooms. We train 1,000 high school, college and university students every year in high-tech R&D and scientific research.

Natural beauty for all to enjoy

Fermilab's site includes more than 1,000 acres of natural prairie, for which the Conservation Foundation has recently recognized us.
The Fermilab site is open to the public seven days a week.

Conclusion

Our top priority and biggest challenge for 2015, 2016,…

- We are preparing to host the world for neutrino science
- We are maintaining a diverse and successful discovery science program, and adding a flagship neutrino science program

Preparing to host the world for neutrinos

A half-century of discovery

Fermilab turns 50 in 2017. Our story has been one of asking big questions and finding a way to discover the answers, and that will be our story for the next 50 years.