



Fermilab: Long-term vision, near-term priorities

Lia Meringa

57th Annual Users Meeting

10 July 2024

Outline

- Introduction to Fermilab
- Vision, Strategy, Near-Term Priorities
 - Particle Physics Initiatives
 - Emerging Technologies Initiatives
 - User and Stakeholder Initiative
- Culture of Excellence Initiative
- Summary

Fermilab at a Glance

- America's particle physics and accelerator laboratory
- Operates the largest US particle accelerator complex
- ~2,100 staff
- 6,800 acres of federal land
- Facilities used by 4,000 scientists from >50 countries

As we move into the next 50 years, our mission remains to solve the mysteries of matter, energy, space, and time for the benefit of all.



Vision for Fermilab 2030

We lead the world in particle and accelerator physics and enabling technologies, underpinned by a diverse and empowered workforce, excellence in laboratory operations, a campus strategy integrated with our science vision and mission-ready infrastructure.

We embrace a culture of safety, discipline and accountability, where every employee exemplifies our core values in doing their work.

Fermilab Mission and Science & Technology Strategy

Fermilab's core mission is to drive discovery, solving the mysteries of matter, energy, space, and time

- Thousands of scientists, engineers, technicians, users, and students from around the globe contribute their expertise to advance the frontiers of knowledge and innovation
- As America's particle physics and accelerator laboratory, Fermilab hosts leading-edge facilities and experiments and develops technologies that support research around the world

Fermilab's science and technology strategy is founded on several strategic initiatives:

- **Five major particle physics initiatives:** Neutrinos, Higgs and the Energy Frontier, Muons, The Dark Universe, and Accelerator Science and Technology
- **Three major emerging technology initiatives:** Quantum Science and Technology, Microelectronics, and Artificial Intelligence
- **One new user and stakeholder engagement initiative**

As our laboratory's mission can only be accomplished by integrating our science vision and our business processes, we prioritize:

- **Excellence in business and lab operations and campus strategy integrated with science vision**
- **Culture of Excellence Initiative**

We must continue to improve our safety performance and safety culture

- **Our ability to perform world class discovery science is underpinned and enabled by excellence in the safe conduct of work.**
- Safety is a core value of our laboratory, across the National Laboratory complex.
- Given the significant world-leading scientific mission of our lab, we must remain diligent in prioritizing the protection of all personnel, the public, and the environment.
- My expectation is that line management understands their responsibilities in implementing ISM across the entire organization.



From June 13, 2024 All Hands

Schedule pressure must never be a justification for deviations from safe work practices



Senior Leadership Team



Lia Meringa
Laboratory
Director



Bonnie Fleming
Deputy Director for
Science & Technology



Greg Stephens
Deputy Director for
Operations



Marc Kaducak
Deputy Director for
Projects (Interim)



Sandra Charles
Chief EDIA
Officer



Beth Fancsali
General Counsel
(Interim)



Jim Kerby
LBNF/DUNE-US
Project Director



Pantaleo Raimondi
PIP-II Project
Director



Anna Grassellino
SQMS Center
Director

Associate Laboratory Directors



Kevin Burkett
Particle Physics



Alexander Valishev
Accelerators



Sam Posen
Applied Physics and
Superconducting Tech



James Amundson
Computational Science
and AI



**Panagiotis
Spentzouris**
Emerging Technologies

Senior Directors



Marc Clay
Environment, Safety,
and Health



Mark Jeffers
Infrastructure
Services



Velma Gordon
Human Resources



**Angela Manning-
Hardimon**
Chief Financial Officer



Jon Bakken
Information
Technology



Joseph Rogers
Security and Emergency
Management



Rae Moss
Communications

Fermilab Core Capabilities

**Accelerator &
Detector Science &
Technology**

**Advanced Computer
Science,
Visualization & Data**

**Large Scale User
Facilities/Advanced
Instrumentation**

Particle Physics

**Mechanical Design &
Engineering**

Microelectronics

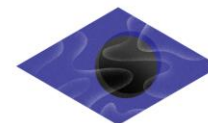
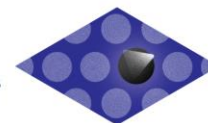
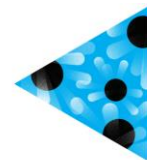
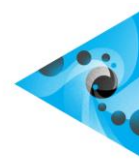
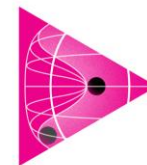
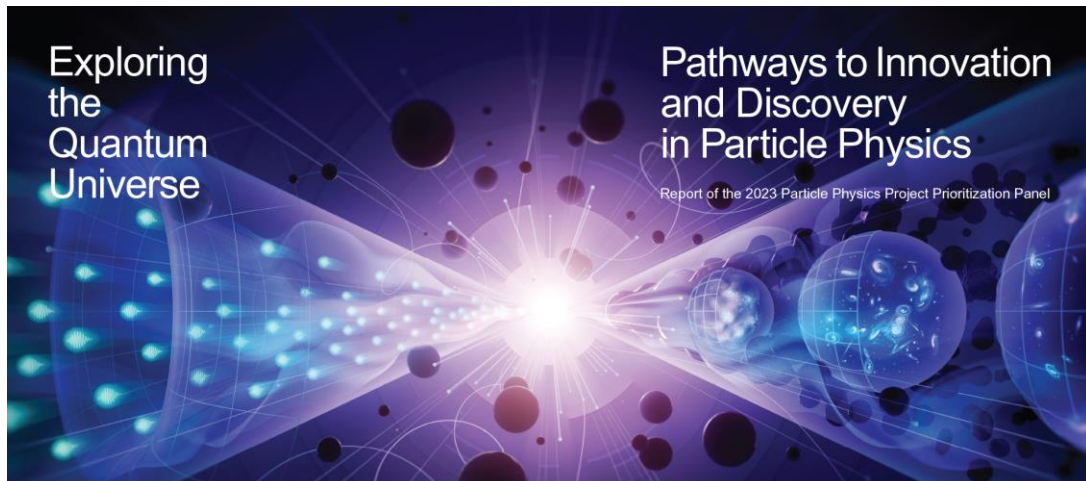
*Emerging,
requested full*

**Plasma & Fusion
Energy Science**

Emerging

**Systems
Engineering &
Integration**

2023 P5 Report

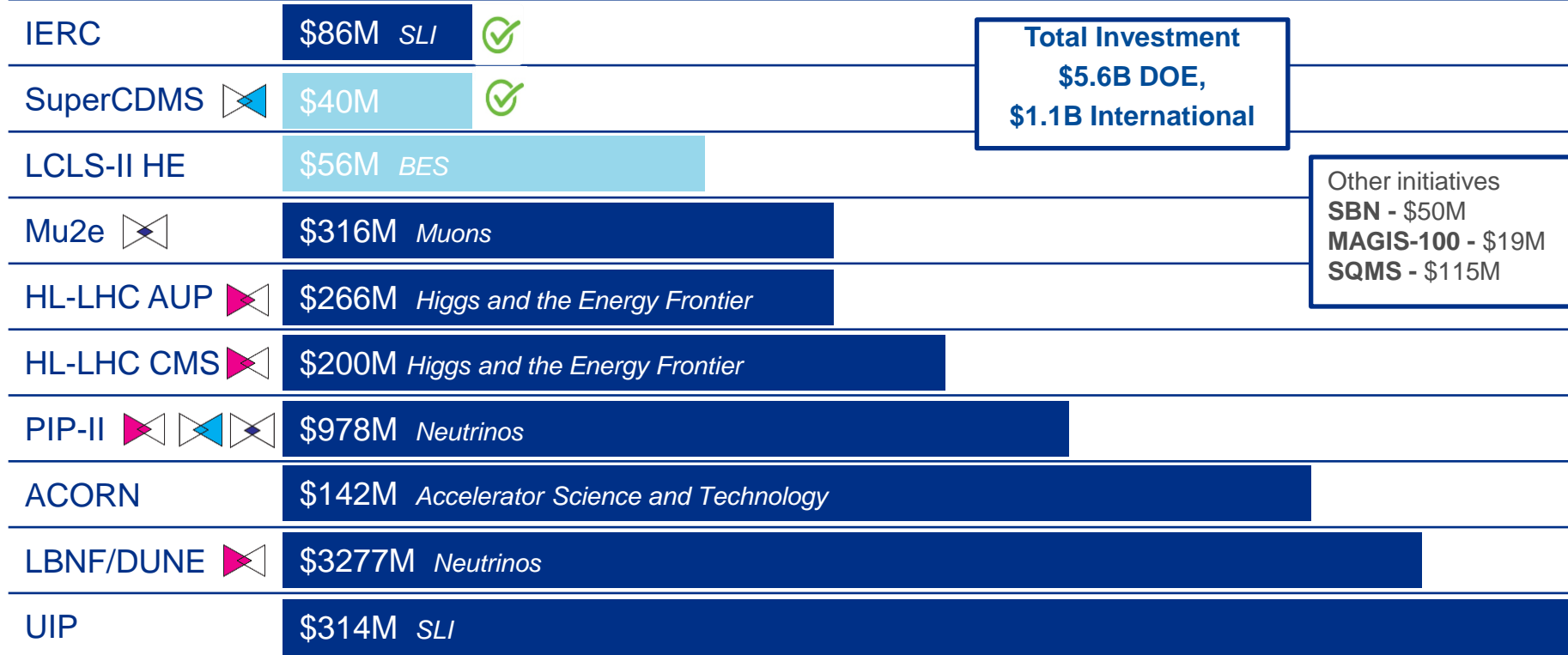


Fermilab's vision is well aligned with the 2023 P5 report

Fermilab executes the P5 plans



FY22 FY23 FY24 FY25 FY26 FY27 FY28 FY29 FY30 FY31 FY32



Total Investment
\$5.6B DOE,
\$1.1B International

Other initiatives
SBN - \$50M
MAGIS-100 - \$19M
SQMS - \$115M

Fermilab executes the largest project portfolio in DOE/SC; >40% scope complete

Fermilab Science and Technology Strategy

Major Particle Physics Initiatives

- Neutrinos
- Higgs and the Energy Frontier
- Muons
- The Dark Universe
- **Accelerator Science and Technology**



Emerging Technology Initiatives

- Quantum Science and Technology
- Microelectronics
- Artificial Intelligence for Science

User and Stakeholder Engagement Initiative

- Discovery on the Prairie



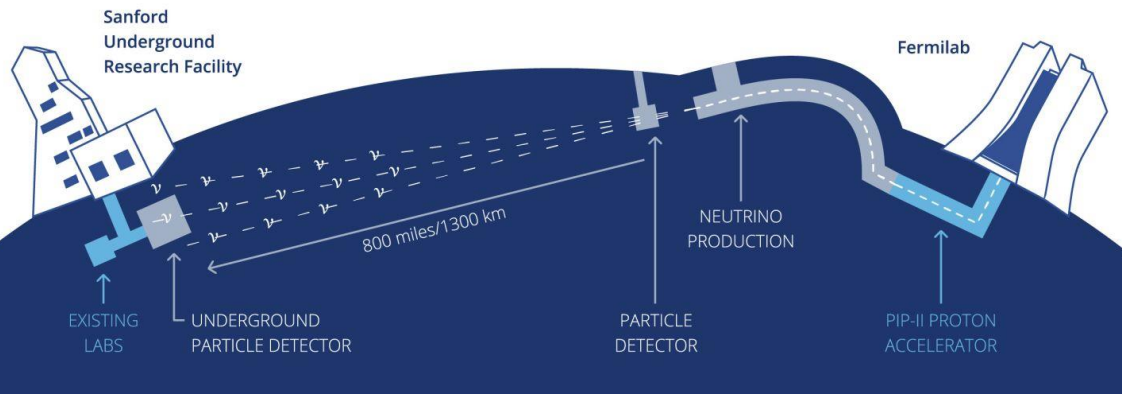
America's Particle Physics and Accelerator Laboratory

- Neutrinos
- Higgs and the Energy Frontier
- Muons
- The Dark Universe
- Accelerator Science and Technology





The *definitive* neutrino oscillation experiment, driven by LBNF and PIP-II



Discovery Potential

- **Neutrino CP violation**
 - The origin of matter in the universe
- **Supernova neutrinos**
 - Origins of neutron stars and black holes
- **Neutrino surprises**
 - New forces, particles, or laws of nature connected to neutrinos
- **Proton decay**
 - Unified origins of particles and forces

The LBNF/DUNE project is the first internationally conceived, constructed, and operated mega-science project hosted by the Department of Energy on U.S. soil

Vision

Remain the undisputed global leader in neutrino science for decades to come, addressing many of the open questions in particle physics today

Initiatives

Operating:

NOvA
SBN: SBND, ICARUS,
MicroBooNE

Projects:

LBNF/DUNE
PIP-II

Future:

DUNE Phase II

Strategy

- Deliver the current neutrino program
- Complete LBNF/DUNE and PIP-II on time, within budget, meeting performance specs
- Realize early implementation of DUNE Phase II via ACE-MIRT and FD3
- Position Fermilab as the DUNE host lab



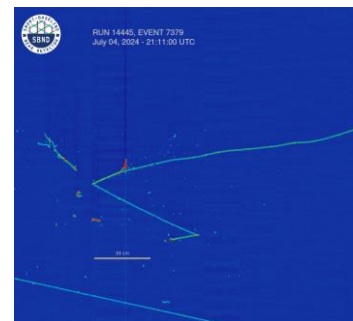
Near-term Priorities

- Operate/Publish New Results
 - NOvA, DUNE 2x2 Demonstrator, ICARUS, SBND
- Construct LBNF/DUNE
 - Cryostat assembly in SD
 - Start Near-site construction
- Construct PIP-II
 - AUP for High Bay Building, Linac Tunnel
 - Commission Cryoplant
 - Complete two prototype cryomodules (SSR2, LB650)



Recent Highlights

- SBND and DUNE ND 2x2 prototype are taking data!
- PIP-II construction progressing at full speed
- LBNF/DUNE
 - Far site excavation 100% complete!

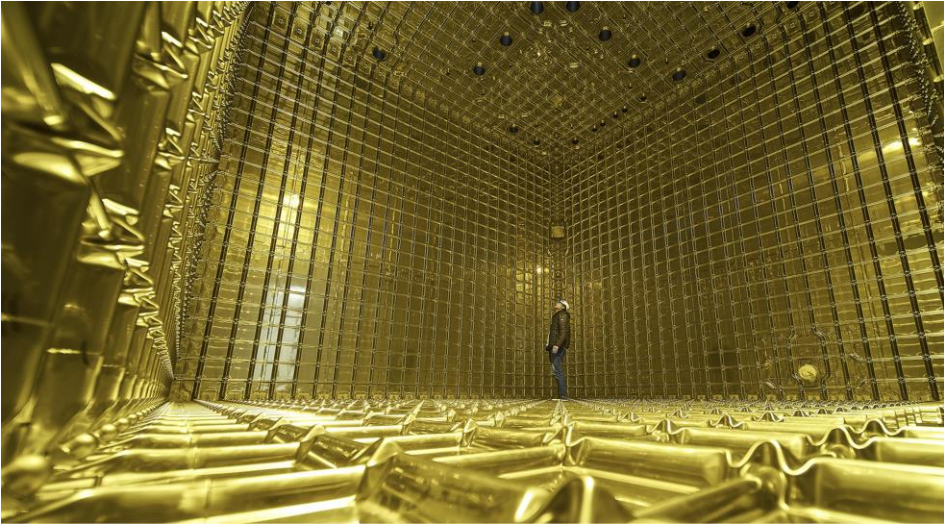


LBNF/DUNE Far Site Excavation is 100% Complete



Celebration planned for August 15, 2024 at 4850L

ProtoDUNE Detectors (Far Detectors 1 and 2) at CERN



CERN Neutrino Platform: first time CERN invests outside Europe



Vision

Be the U.S. leader in the energy frontier and a partner of choice for the development of novel approaches to exploration of the Higgs sector and in enhancing the capabilities of precision multi-TeV colliders to probe previously unexplored energy scales

Initiatives

Operating:
LHC CMS Experiment

Projects:
HL-LHC AUP
HL-LHC CMS Detector Upgrade

Future:
FCC-ee
Muon Collider

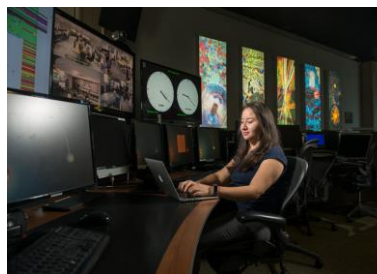
Strategy

- Continue to lead U.S. CMS operations and LHC physics analysis
- Complete the HL-LHC Upgrade Projects
- Lead accelerator and detector R&D toward an off-shore Higgs factory
- Lead international efforts for a U.S.-hosted muon collider



Near-term Priorities

- LHC CMS Operations
- Construct HL-LHC AUP
 - Deliver 7 cryoassemblies to CERN, all crab cavities
- Construct HL-LHC CMS Upgrade
 - Full production
- FCC-ee
 - Apply core capabilities to R&D, prototyping



Recent Highlights

- HL-LHC
 - HL-LHC CMS Upgrade achieved CD-3
 - First U.S.-built cryoassembly delivered to CERN
- Excellence in U.S. CMS Operations
 - Over 20 publications since Spring '23
 - CMS night shifts covered from ROC
 - High performing Tier-1 center
 - LPC is a key element of U.S. CMS providing education, training, user support





Vision

Fermilab is a world center for accelerator-based Charged-lepton flavor violation (CLFV) and Dark Matter experiments, driven by intense particles beams and PIP-II/ACE

Initiatives

Operating:
Muon g-2 (recently ended run)

Projects:
Mu2e

Future:
Next-generation muon experiments

Strategy

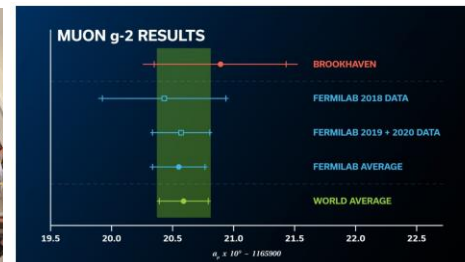
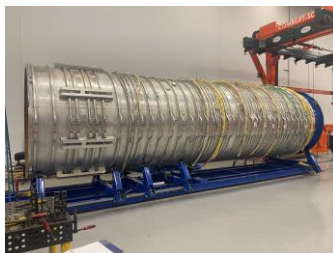
- Complete Muon g-2 and Mu2e experiments
- Use the upgraded accelerator complex to enable a next generation of muon experiments, e.g. beam dump experiments at PIP-II
- Begin an R&D program for a next-generation muon facility

Near-term Priorities

- Muon g-2
 - Publish result of full dataset, updates from theory initiative
- Mu2e
 - Mu2e Project Complete
 - Transition to operations

Recent Highlights

- Muon g-2
 - Published world's most precise measurement of muon g-2
- Mu2e
 - Mu2e Project is 91% complete
 - Two transport solenoids were safely delivered to the Mu2e experimental hall



The Dark Universe

Vision

Fermilab is an essential partner in cosmic science experiments and is contributing innovative R&D efforts toward future dark energy, dark matter, and cosmic microwave background (CMB) experiments

Initiatives

Operating:
Rubin/LSST
ADMX-G2
SPT-3G

Projects:
DMNI
CMB-S4

Strategy

- Search for dark matter across a wide mass range leveraging Fermilab's instrumentation facilities/capabilities
- Support the advancement of CMB experiments while playing key roles in current and upcoming surveys to study cosmic acceleration

Near-term Priorities

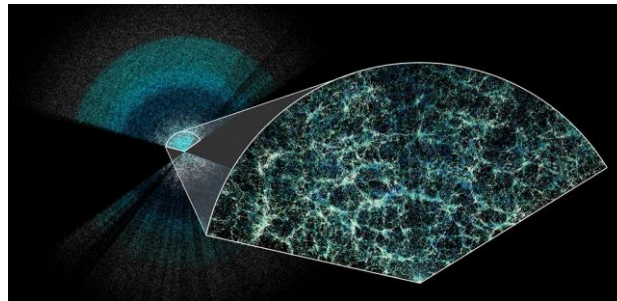
- Support current operations: Rubin/LSST, SPT-3G, SCDMS
- ADMX-G2: Continue run searching for the QCD axion
- Dark Matter New Initiatives (DMNI)

Recent Highlights

- ADMX-G2
 - Began a two-year run in December searching for the QCD axion in the 1020-1390 GHz region
- ADMX-EFR
 - 9.4T MRI magnet from UIC arrived at Fermilab



South Pole Telescope during 2022 Austral winter survey observations (Credit: Aman Chokshi)



The Dark Energy Spectroscopic Instrument (DESI) has made the largest 3D map of our universe to date



Accelerator S&T – World-leading Capabilities

Fermilab is addressing the needs of many SC programs

BES

FES

NP

ASCR

Accelerator and Beam Physics

- IOTA/FAST beam-test facility advances critical R&D enabling next-gen accelerators for DOE/SC

Superconducting Radio-frequency

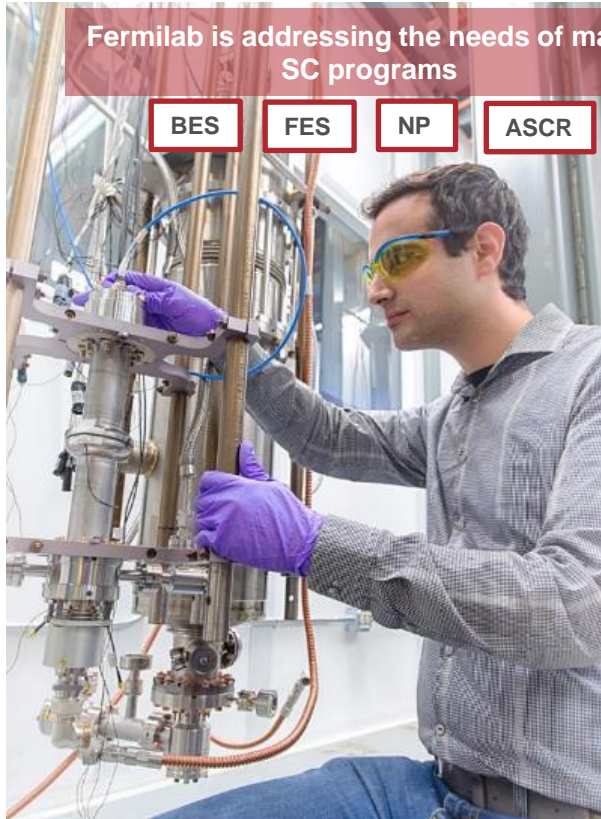
- Fermilab continues to produce world-class cryomodules for LCLS-II HE, PIP-II, applying developments to FCC-ee

High-power Targetry

- Fermilab leads the Radiation Damage in Accelerator Target Environments (RaDIATE) collaboration

High-field Magnets

- HEP and FES: New high field magnet cryogenic test stand at Fermilab to perform R&D of high-temp superconducting cables for future fusion reactors

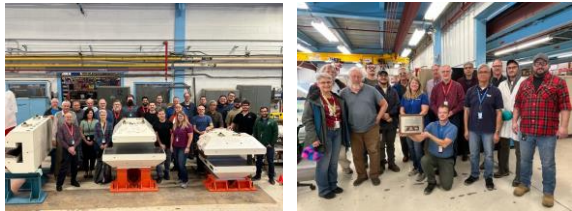


Accelerator Technology Enables DOE/SC Mission Beyond HEP

Basic Energy Sciences



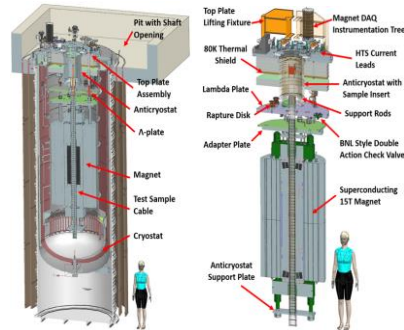
LCLS-II and LCLS-II-HE at SLAC – enabling technology R&D and half of cryomodule production



SNS PPU at ORNL – Chicane and dump dipole magnets

Possible future engagement: SNS STS

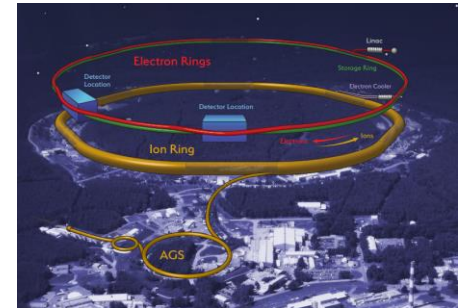
Fusion Energy Sciences



HFVMTF at Fermilab – Joint HEP/FES facility – test stand under fabrication to enable high field testing of magnet conductor

Engagement is increasing under our emerging core capability; growing our partnership with PPPL; program provides excellent opportunity for workforce development

Nuclear Physics



EIC at BNL – engaged and ready to do more: Magnet design and simulation, G. Apollinari: Chair of the EIC Magnet Steering Group

Possible future engagement: 3 GeV SRF linac injector

Accelerator S&T and Operations

Vision

Be the world's preeminent particle accelerator facility and advance leading-edge accelerator technologies and knowledge



SSR2 Cryomodule Cavity



MI-8 Collimator Pre-assembly

Strategy

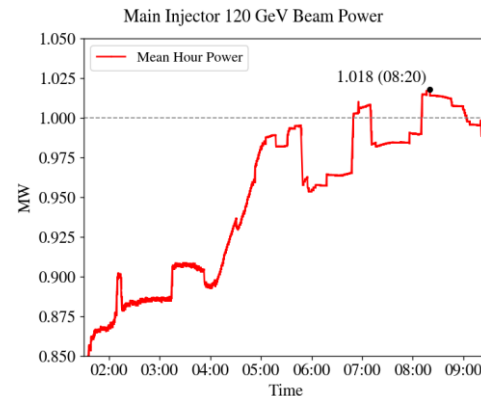
- Modernize accelerator operations
- Upgrade the accelerator complex to deliver 2 MW to DUNE
- Enable an offshore Higgs factory
- Develop a 20-year strategic plan for accelerator complex
- Leverage and develop Fermilab accelerator S&T in support of broader DOE/SC programs

Near-term Priorities

- Accelerator Complex Ops
 - Support 40 weeks of operations reliably in FY25
 - Prioritize maintenance of mission-critical equipment
 - Modernize accelerator operations
 - Transition Mu2e, PIP-II to operations
- Execute ACORN
- Launch ACE-MIRT
- Advance Accelerator R&D
 - SRF, high field magnets for FCC-ee, future accelerators
- 20-year Strategic Plan for accelerator complex
 - Launch national task force

Recent Highlights

- Accelerator Complex operates under fully approved Accelerator Safety Documentation O 420.2D
- Achieved beam power record of 1 MW at 120 GeV by reduced Main Injector cycle time



Fermilab Accelerator Complex Evolution (ACE)



Accelerator Complex

Campaign of upgrades, modernization, investments critical for the success of DUNE

PIP-II Project

Other projects, e.g. ACORN, to ensure accelerator complex is compatible with PIP-II

ACE-MIRT

Faster delivery of DUNE science: capability \times capacity \times reliability

20-year strategic plan

ACE-BR, Muon Collider



Deliver groundbreaking science & technology innovation

Fermilab Accelerator Complex Modernization Initiatives

GOAL: Highly effective, efficient accelerator operations with a modernized control system, work and lab spaces and integration of emerging technologies like robotics and AI/ML for accelerators



Accelerator Controls Operations Research Network (ACORN)

- DOE O413 project to modernize the accelerator control system and replace end-of-life power supplies; partnership with ORNL and INL

Robotics Initiative

- Motivated by need to increase worker safety and efficiency for accelerator and target operations

Center for Accelerator Science and Technology (CAST)

- Proposed building to include updated Main Control Room, co-located controls and instrumentation staff and space for USPAS, visiting scientists and engineers

Largest accelerator complex in the U.S. and the only one in the world to produce both low- and high-energy neutrino beams and enable precision science experiments

Emerging Technologies/ National Initiatives

- Quantum Science and Technology
- Microelectronics
- Artificial Intelligence for Science



Quantum Science and Technology



Vision

Be a world leader in developing and deploying innovative quantum technologies **at scale**.

Utilize quantum technologies as **new tools to address grand challenges** facing particle physics, and the broader DOE/SC programs.



Fermilab's open-source Quantum Instrumentation Control Kit (QICK)

Strategy

Leverage core HEP accelerator/instrumentation capabilities at Fermilab to advance QIS&T

Lead the QIS Center SQMS, the international leader in superconducting quantum systems for computing and sensing

Advance DOE QIS research programs, develop and demonstrate key systems for a quantum internet and distributed sensing

Continued leadership and participation in SQMS and QSC, contribute to DOE SC programs, to **foster interdisciplinary research**, to grow the **national quantum ecosystem** and a skilled and diverse quantum workforce



New underground qubit testing facility

Fermilab's Unique Capabilities into Quantum Ecosystem

Leaders in SRF technology and superconducting materials for QIS

Deployed first quantum processors prototypes on-premise at SQMS garage mK cryogenics expertise: new technologies for efficient large scale QIS facilities

Metropolitan scale quantum network connecting FNAL, ANL, Northwestern

Low cost, scalable, open-source quantum control and readout systems

Algorithms for HEP quantum field theory simulation and fundamental physics

Advancing quantum systems through partnerships with Rigetti, IBM, Google...



First U.S. QIS 5 DOE Centers school launched and host at Fermilab

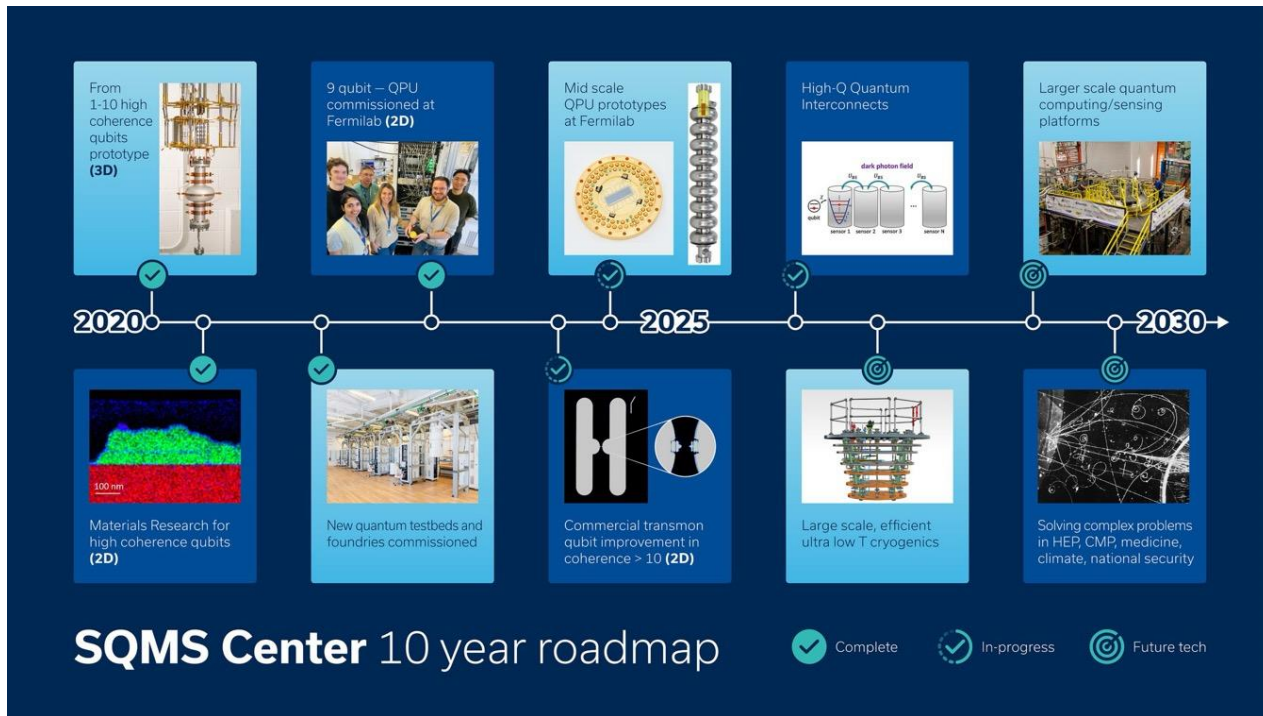


SQMS: delivering on the plan, ambitious roadmap for the future

- Mission-driven DOE National Quantum Information Science Research Center with deliverables and milestones

Delivered on the plan

- Advanced the scientific understanding of materials losses in qubits
- Demonstrated world leading coherence time for 3D and 2D qubit systems
- Developed unique large-scale facilities for QIS devices fabrication and characterization
- Developed first mid-scale processor prototypes, in collaboration with industry
- In coordination with the other NQISRCs, fostered interdisciplinary research, and **stewarded of the quantum ecosystem**
- In next five years, continue to tackle decoherence and scalability technology challenges and **applications of quantum systems for DOE SC**



SQMS is contributing to the development of the DOE QIS roadmaps, and is leading the NQISRC council supporting the creation of the 5 Center joint website, the first national quantum database and other joint efforts

Microelectronics

Vision

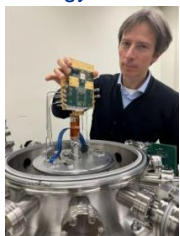
Become a technology leader for developing the next generation of microelectronics for science, energy efficient and capable of operating in extreme environments, and create disruptive technologies for achieving societal impact

Objectives:

Enable breakthrough science discovery through precision instrumentation

Develop impactful hardware for advancing applications of QIS, edge AI, and beyond

Support U.S.-based manufacturing technology



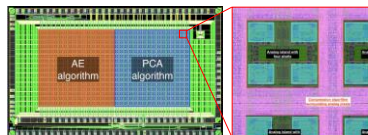
Davide Braga,
lead PI of the
HYDRA DOE
co-design center

Strategy

Leverage core capabilities developed for our HEP program and work with academic and industry partners with complementary expertise to

- (1) Lead and participate in DOE ME science research centers
- (2) Participate in DoD Microelectronics Commons hubs
- (3) Support and participate in regional efforts for DoC NSTC projects and lead regional efforts for a DoC Heterogeneous Integration pilot facility.

Establish a regional consortium for microelectronics to expand and grow the community and train the future workforce



Fermilab's Unique Capabilities Grow the Microelectronics Ecosystem

Design of application-specific integrated circuits (ASICs), sensor codesign, and system integration for HEP experiments and other DOE programs

Edge-AI, AI-on-chip: leading expertise in developing tools, methodology, and hardware; demonstrated by the HL-LHC CMS upgrade chips (ECON-T).

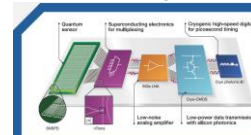
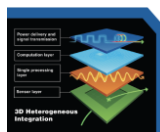
3D integration: 18 years of experience in enabling 3D Heterogeneous Integration in the ME ecosystem. Contributed to current industry standards for hybrid bonding.

Sensors-on-chip: Monolithic integration of sensor and readout electronics for many detector applications

Cryogenic electronics: silicon-proven IPs and design methodologies (for QIS sensor and computing applications). Developed the first cryo process design kit for Global Foundries.

Extreme environment characterization & testing of integrated circuits, sensors, and electronic systems, in radiation and cryogenic environments. Utilize Fermilab's test beams, irradiation, and cryogenic testing facilities and probes.

Workforce development: Unique opportunities through chip design internships



Artificial Intelligence for Science

Vision

Lead the community in the deployment of intelligent sensing for science, enabling experts, tools, technologies, and platforms



Wilson Hall
ONE WEST

9 AM - 4:30 PM

Agenda:
Overview of AI & HEP
Example Applications
Panel Q&A
Idea Incubator

Idea Incubator:
Stick around for coffee and snacks and share your AI work or discuss interesting applications with experts and enthusiasts by making an AI flyer!

AI JAMBOREE
10/23/2023

LEARN MORE ABOUT THE AI ACTIVITIES AND PLANS AT FERMILAB

LEARN MORE AND REGISTER AT:
<https://indico.fnal.gov/a/jamboree23>

Strategy

- Leverage Fermilab's lead in developing AI-enhanced sensors
- Develop AI workforce through knowledge transfer from AI expertise across and beyond Fermilab
- Cultivate and strengthen industry collaborations through common progress in sensing and fast AI technologies

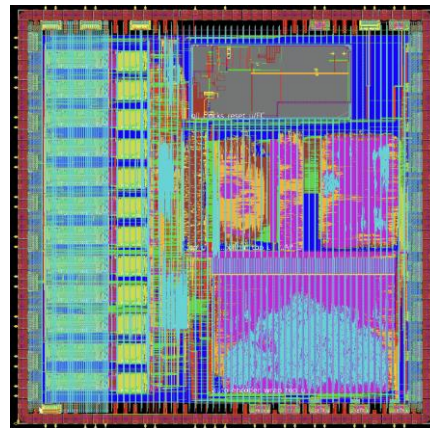
Near-term Priorities

- Improved accelerator operations through AI-enhanced controls and digital twins
- Real-time data filtering for experiments including DUNE, CMS, and Rubin

Fermilab's Unique Capabilities in AI for Science

Fermilab is a leader in intelligent sensing and real-time AI

- Driven by extreme data rates from HEP science
- Leveraging capabilities in microelectronics and efficient AI codesign
- Driver of the Fast ML for Science community and hls4ml tool
- Developing cross-domain and industry partnerships



User and Stakeholder Initiative: Discovery on the Prairie



Partnerships are Central to Mission Success

Lia Meringa and Mark Thomson, executive chair of the Science and Technology Facilities Council, U.K.

Research and Innovation, sign a certificate to commemorate the international cooperative research and development agreement that fortifies R&D and experimental activities among Fermilab and U.K. institutions for the MAGIS-100 experiment.



International

- HEP science is driven through broad multi-national collaborations
- Major in-kind contributions critical to flagship projects

Lia Meringa and xLight, Inc. CEO Nicholas Kelez shake hands to solidify a new partnership that will transition technologies developed at Fermilab for commercial applications.



National

- Expansive university engagement, including MSIs, builds a future workforce
- Industry engagement supports U.S. competitiveness

Fermilab's Office of Education and Public Engagement hosted the 2023 Outdoor Family Fair, which brought the public to the lab to enjoy educational activities about its science, including the popular Mr. Freeze cryogenic show, and get a close look at Fermilab's diverse site.



Regional

- Support economic development initiatives
- Chicagoland as a quantum technology hub
- STEM Outreach – Lederman Science Center, Saturday Morning Physics, etc. teach and inspire educators and the next generations

Discovery on the Prairie

An integrated, long-term vision for Fermilab that expands our impact for the nation, high-energy physics, and our state and local communities

Plan

- Revitalization of campus and infrastructure driven by community needs in the DUNE era
 - Reimagined Fermilab Village
 - **Phase-I housing development - \$30M investment from State of IL**
 - Modern daycare, recreational and community amenities
 - A new, world-class STEM and community-outreach facility
- Technology and Innovation Park with university and industrial partners for maximizing Fermilab's impact in science, society and industry

Near-term priorities

- Move Labs out of the Village
- Release IL State funding, begin construction of Phase I housing facility
- Plan a new centralized Machine Shop



We are transforming our Campus

S&T Strategy

Neutrinos

Higgs and the Energy Frontier

Muons

The Dark Universe

Accelerator Science & Technology

Quantum Science

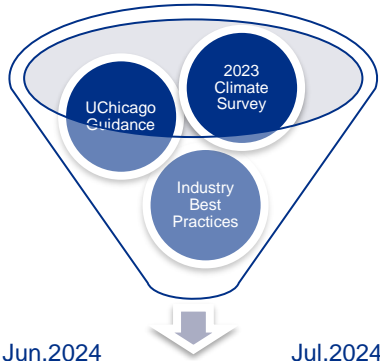
Microelectronics

AI for Science

Discovery on the Prairie



Culture of Excellence Initiative



Culture of Excellence Initiative Goals

- Establish a mission-oriented Culture of Excellence to maximize the performance of our organization
- Drive culture change across the HEP Community through exemplifying our Core Values



- Conceptualize Framework
- Collect industry best practices
- Consult University of Chicago
- Plan employee engagement forums

- Establish Core Values through forums with lab leadership, supervisors, laboratory resource groups
- Collect list of principles and behaviors consistent with Core Values directly from employees
- Assemble Core Values, principles, and behaviors into a framework that represents the vision of our Culture

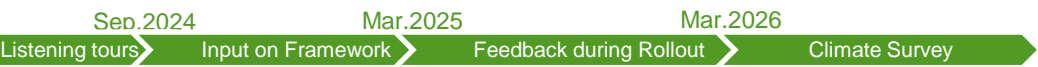
- Communicate Culture Vision consistently and continuously
- Incorporate Core Values into all aspects of doing business

- Employees trust leadership and each other
- Employees feel their work is meaningful, significant, and purpose-based
- Employees take pride in their work and feel accountable
- Positive reinforcement of behaviors that exemplify the Core Values
- Organization is flexible and continuously learning
- 2026 Climate Survey reflects progress

Core Values → Culture

Culture of Excellence Leaders:
 Velma Gordon – Chief Human Resources Officer
 Marc Kaducak – Chief Project Officer

Continuous Employee and User Engagement Throughout
 Senior leadership meets with small groups of employees and users



Summary

Fermilab continues to deliver world-class science, project execution, and technology innovation, with safety as the highest priority.

We have a bold, yet realistic 10-year vision aligned with DOE-SC program and the 2023 P5 Report.

- Our vision, strategy and near-term priorities are defined for each of our major initiatives:
 - Particle Physics
 - Emerging Technologies
 - Users and Stakeholder Engagement
- The mission requires initiatives for integration of the science vision and business functions:
 - Executing our plans to achieve Excellence in Laboratory Operations and Campus Strategy
 - Culture of Excellence initiative - safety, discipline, and accountability

We are determined to strengthen the culture of our community and lead the lab to unprecedented heights of scientific discovery and technology innovation.

***We are grateful to DOE and our community of Users and Partners
for your support and engagement!***