Fermilab Strategy and Vision

Nigel Lockyer, Laboratory Director

Users Meeting

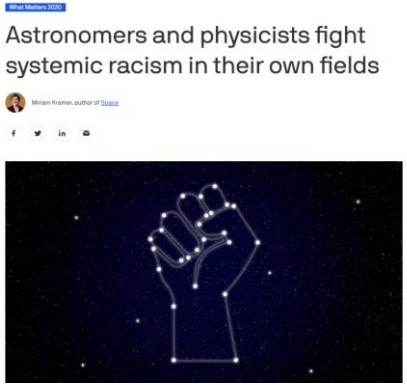
10 August 2020

Diversity and Inclusion – Lab Priority

Science community and lab leadership imperative
- Following AIP Strategic Framework
- Support for community action (Particles for Justice, ShutDownStem, etc.)

Actions focused on **lasting change**
- Listening sessions with Lab Resource Groups; response plan developed to address concerns
- Action plans for Climate Survey feedback at Lab, Division, Section levels
- Changes to hiring, personnel evaluation, and career planning processes
- Analysis of equity in positions, promotions, pay, performance reviews, awards processes
- **New Chief Equity, Diversity and Inclusion Officer role** – internal/external communications on EDI, diversity outreach, resource groups

AIP Adopts Statement on Diversity, Equity, and Inclusion



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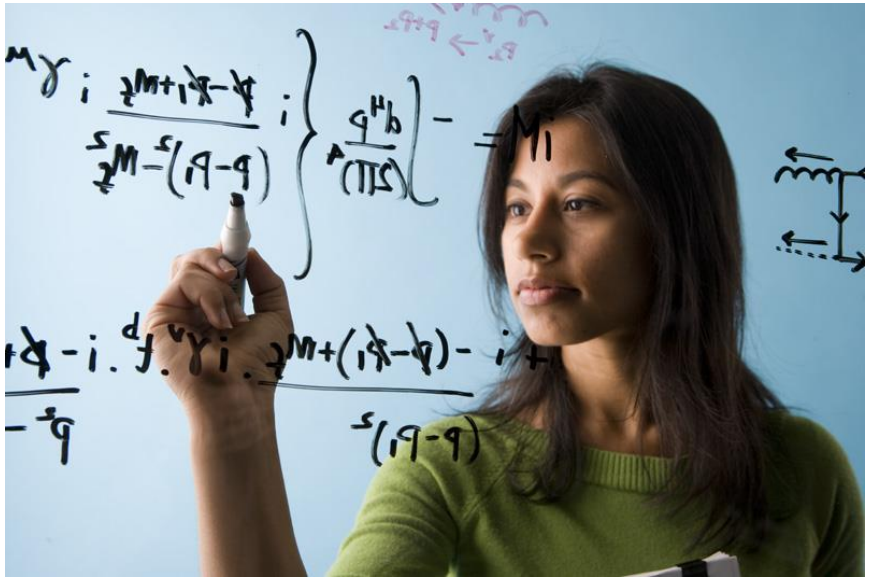
ONE CAN CHANGE THE WORLD

P5 Science Drivers of Particle Physics

- Higgs boson
- Neutrinos
- Dark matter
- Dark energy and inflation
- Exploring the unknown



Achieving the science goals requires technology innovation

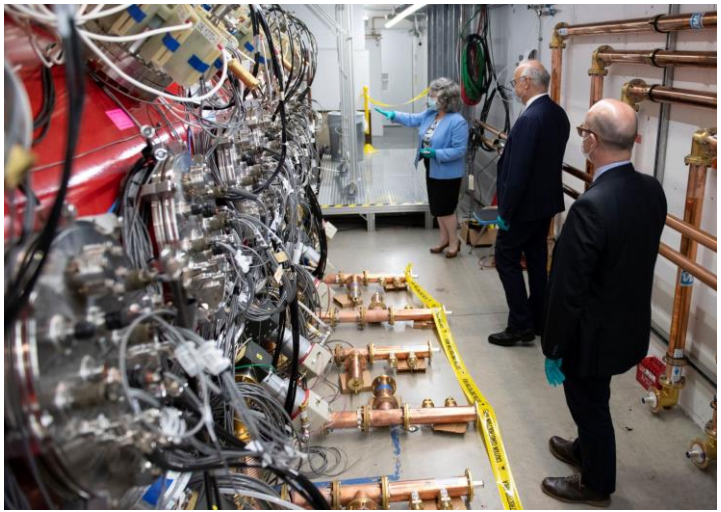
- All the easy experiments have already been done
- Pushing the boundaries of technology enables new experiments

International Engagements

- DOE – Fermilab led efforts in securing in-kind contributions with legally binding agreements for PIP-II, LBNF/DUNE, SBN
  - Project Annex: Signing of U.S./UK international agreement in January 2020
  - At the U.S.- Brazil JCM: Signing of an I-CRADA agreement : UNICAMP and Fermilab and MOU: FAPESP and Fermilab March 2020
  - I-CRADA : Fermilab - Wrocław University of Science and Technology (WUST) in January 2020
  - I-CRADA : Fermilab - Univ of Bern for DUNE near detector and SBN – November 2019

International Engagements – Ambassador of France

- H.E. Philippe Etienne, Ambassador of France to the U.S. Guillaume Lacroix Consul General of France, Chicago visit Fermilab
- Engagements with the French institutions CEA, CNRS, IN2P3 and industries Air Liquide, GTT are paving pave path towards greater scientific collaboration, to the joint design and delivery of components for the accelerator and neutrino program.



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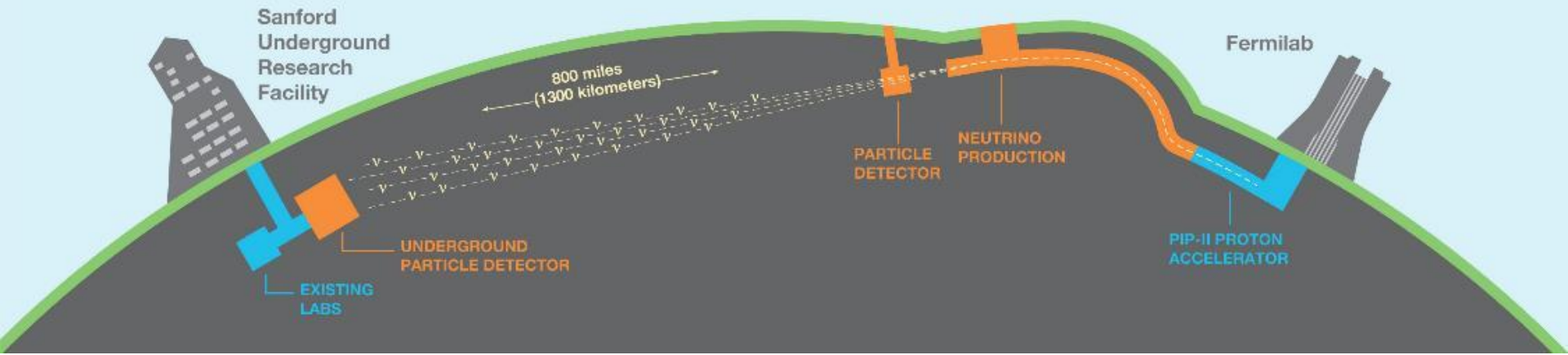
DEEP UNDERGROUND NEUTRINO EXPERIMENT

Currently: 1,214 collaborators from 202 institutions in 33 countries (including CERN)



Origin of matter. Investigate leptonic CP violation. Are neutrinos the reason the universe is made of matter?

Neutron star and black hole formation. Ability to observe neutrinos from supernovae events and perhaps watch formation of black holes in real time.

Unification of forces. Investigate nucleon decay.

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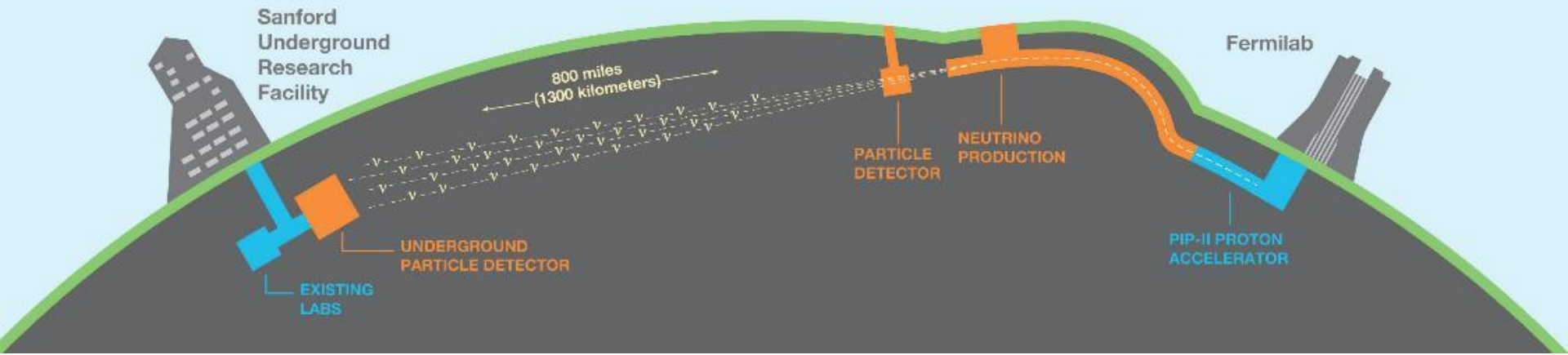


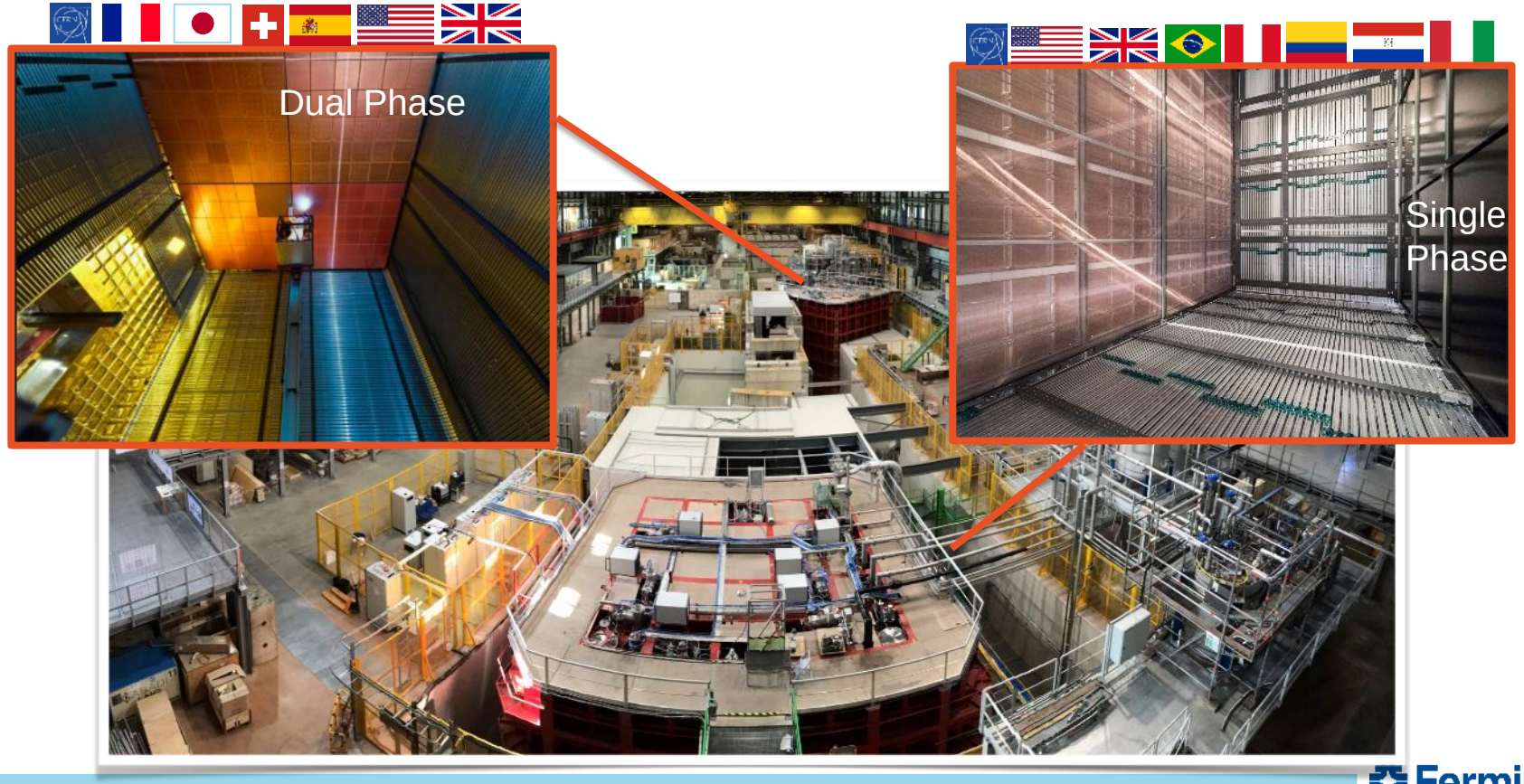
Intense Beams: Required to produce and detect ghostly neutrinos

Long Baseline: Matches the physics goals of oscillations

Liquid Argon: Capable of revealing exquisite detail of ν interactions

Deep underground: Reduced backgrounds for ν's and other science

ProtoDUNEs



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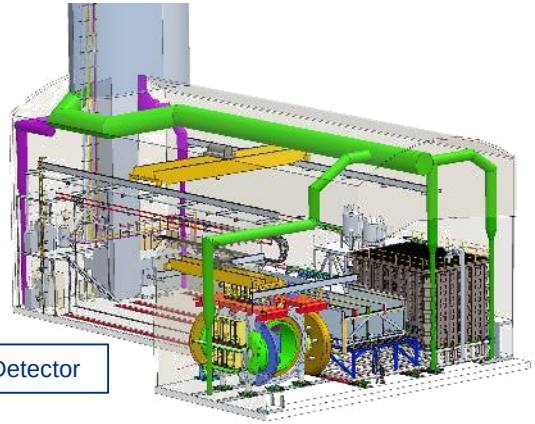
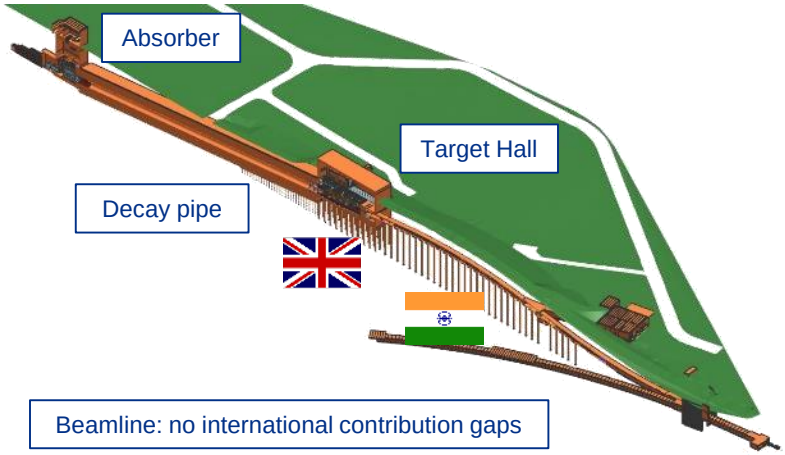
LBNF/DUNE-US – at the Near Site at Fermilab

- 100% preliminary design (60% overall) for conventional facilities completed
- Conceptual Design Report for Near Detector submitted to Long-Baseline Neutrino Committee for technical review ➔
- Beamline design at 57% complete overall
- Site preparation work underway ➘



Day One Near Detector



Beamline: no international contribution gaps

Installation of new power and communications ductbank

Installation of Indian Creek culvert reroute

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LBNF/DUNE-US – at the Far Site – Pre-Excavation Work

4,200LF Rock Conveyor to deposit excavated rock into the Open Cut in Lead, SD – Installing across U.S. Rt 85

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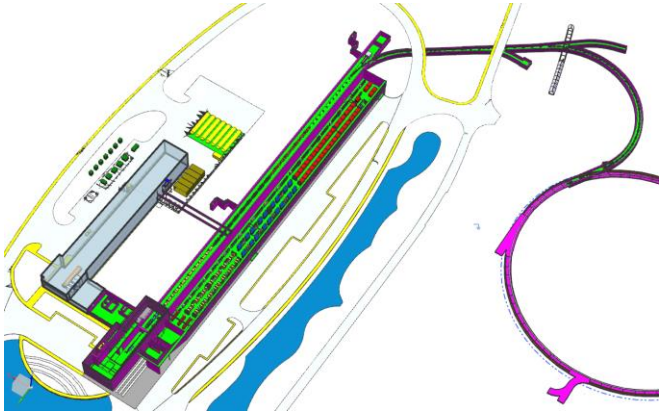
Proton Improvement Plan – II (PIP-II)

P5 Report defines PIP-II Mission

PIP-II will enable the world's most intense beam of neutrinos to the international LBNF/DUNE project, and a broad physics research program, powering new discoveries for decades to come.

PIP-II linac capabilities

- Beam Power
  - 1.2 MW proton beam
  - Upgradeable to multi-MW
- Flexibility and multi-user capability
  - CW-operations
  - Customized beams
  - Multi-user delivery
- Reliability



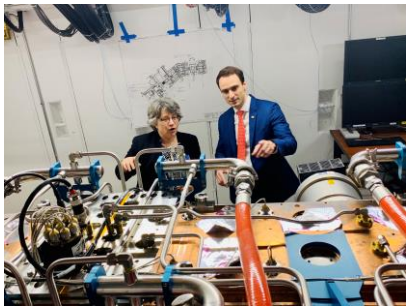
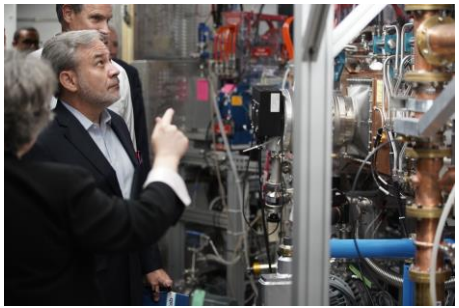
PIP-II Scope

- 800 MeV H− linac
- Linac-to-Booster transfer line
- Upgraded Booster
- Upgraded Recycler & Main Injector
- Conventional facilities

PIP-II will provide highly capable, reliable, and upgradeable scientific infrastructure with significant savings to DOE

Excellent progress on all fronts: Support, reviews

- ✓ Strong support from OHEP, Office of Science, DOE, Congress
- ✓ Excellent reviews, incl. CD-2/3a IPR review in Jan 2020

Excerpts from CD-2/3a IPR:

"..tremendous positive progress since the last review, ..we commend the project team!"
"… team is motivated and has the experience to successfully deliver scope of work"
"Partner Laboratories were well represented ….successfully communicated their passion for the project and their reasons for contributing to PIPII"
"… impressive PIP2IT facility"

Excellent progress on all fronts: ECF subproject approved

- ✓ CD-2/3 approval of Early Conventional Facilities (ECF) subproject
  - Thank you to DOE/SC leadership for your support!

PIP-II Injector Test Facility (PIP2IT): Testbed for PIP-II Front End

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PIP-II is on track to baseline in 2020

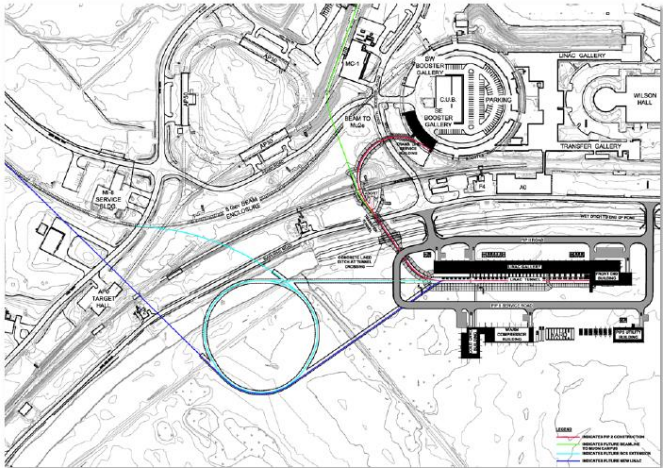
- PIP-II is on track to baseline in fall 2020
- Leveraging the expertise and contributions from International partners to build a highly capable accelerator

We are grateful for continuing strong support from DOE/SC

How to get to 2.4 MW

- P5 plan calls for 2.4 MW on target for neutrinos
- PIP-II gets us to 1.2 MW. Booster Replacement gets to 2.4MW

- Working group of national & international experts in particle physics & accelerator technology to assess science opportunities and technology choices
- Goal is to submit white paper before Snowmass



- Booster Replacement schedule is driven by need to meet P5 2.4 MW plan and to meet physics goals as early as possible

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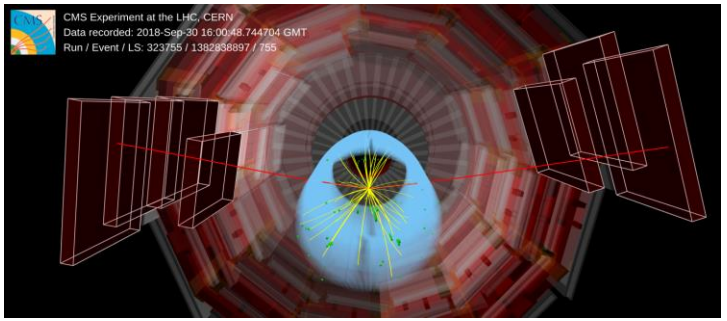
Collider Science and CERN

- CMS submitted its **1000th publication**
  - Key role played by Fermilab scientists
- HL-LHC CMS Detector Upgrade project
- HL-LHC Accelerator Upgrade project
- LHC Physics Center (LPC) engages US & world-wide collaborators / young scientists
- New results continue. This week $H^0 \rightarrow \mu\mu$ which was enabled in part by AI/ML.

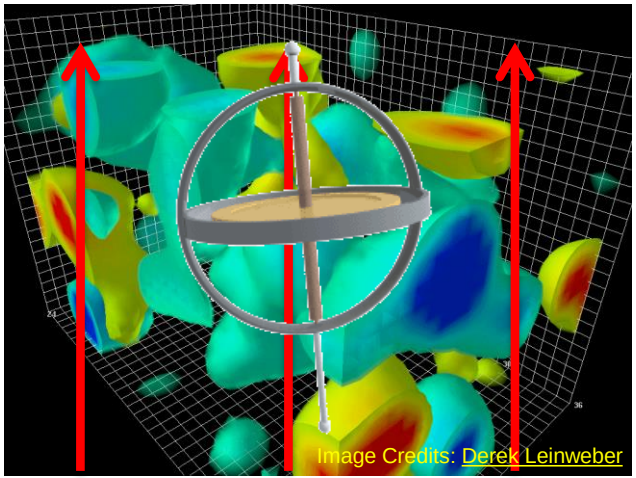


CMS event display of dimuon Higgs candidate


Fast Machine Learning (ECA 2019: N. Tran)

Precision Science: Muon g-2

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

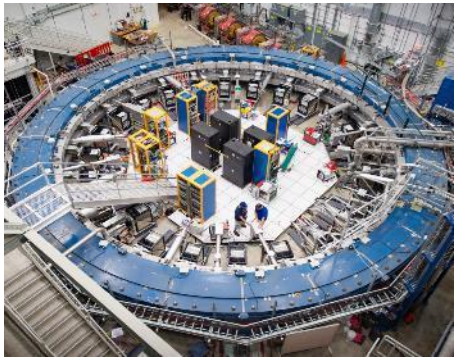


Lab objectives:

- Collect 12x BNL raw data set by end of 2021
- Publish 1st results exceeding BNL precision in 2020
- Collect 20x BNL E821 data set by end of 2022

Recent achievements:

- Improved temperature/field stability and implemented final round of accelerator kicker upgrades



nature Subscribe

NEWS - 20 DECEMBER 2019

The science events to watch for in 2020

Cosmic Science

Goals:

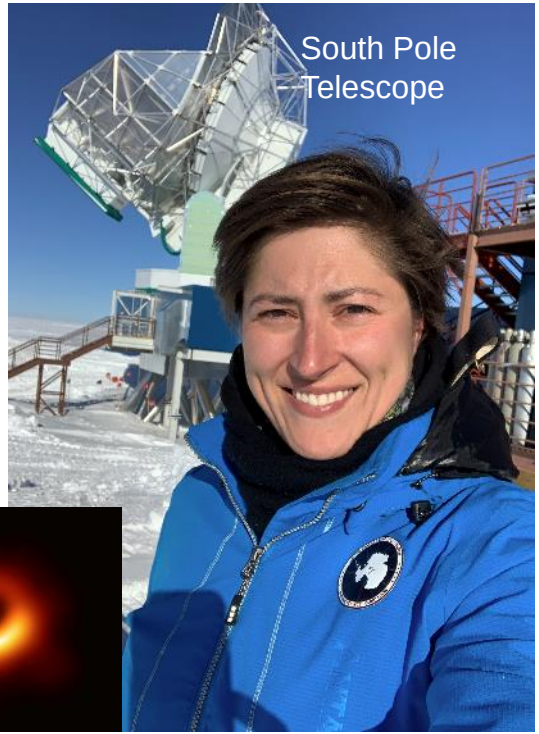
- Strategic plan: Growth areas in CMB and Axions
- Science goals: Dark Energy, Inflation, Neutrinos, Dark Matter

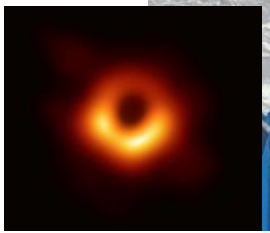
Recent achievements in Cosmic Surveys:

- Dark Energy Survey (DES) complete, now continue to extract science. Already with 250+ publications.
- South Pole Telescope (SPT-3G) – through 2023 producing world leading results with early data.

Recent achievements in Dark Matter (DM):

- Novel CCD-based experiments SENSEI -> OSCURA.
- Wave-like DM: Axion Dark Matter Experiment (ADMX) Extended frequency range involves quantum sensors.





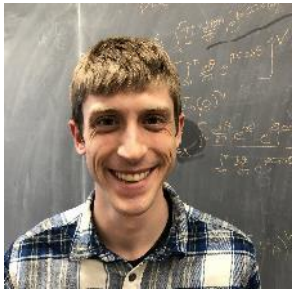
Sasha Rahlin, FNAL Postdoc
2020 Breakthrough Prize co-awardee

Theory

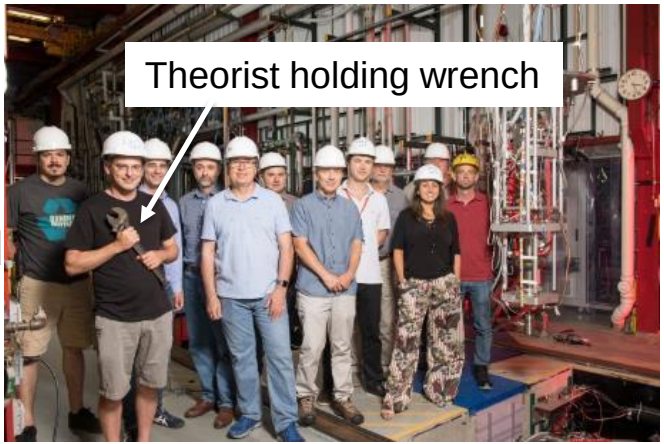
Core strength in areas directly related to the Fermilab experimental program

- Support neutrino program in neutrino nuclear interactions (N. Rocco, M. Wagman)
- Develop physics beyond the Standard Model of particle physics and cosmology
- Extract science from the LHC & g-2
- Co-lead SRF experiment for dark photons
- Develop innovative quantum computing applications and machine learning techniques for cosmology and event generators.

N. Rocco



M. Wagman



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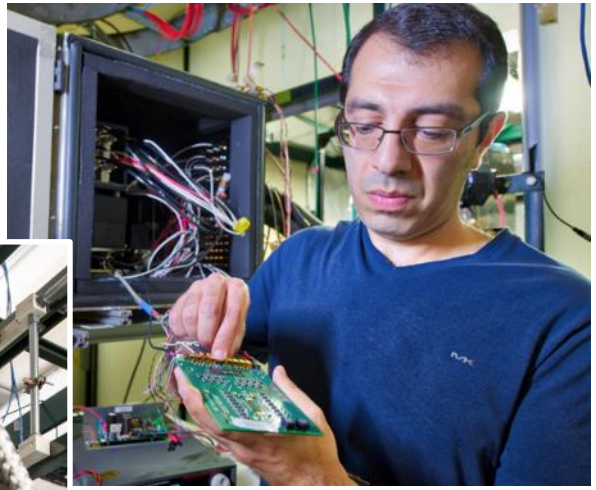
Detector R&D

5-year strategic plan aligns with DOE Detector Basic Research Needs…. many collaborations with national labs and universities

- Increasing priority for strategic areas:
  - Picosecond Timing
  - Argon and Xenon Detectors
- Continued excellence with
  - Application Specific Integrated Circuits (ASICs)
  - Novel dark matter detectors
  - Programmatic blue-sky R&D



Both detector R&D efforts shown began as LDRD and continue as Early Career Awards

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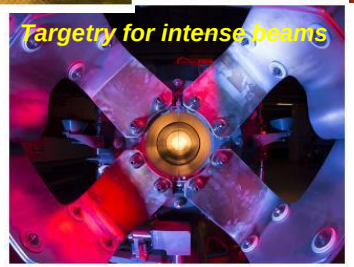
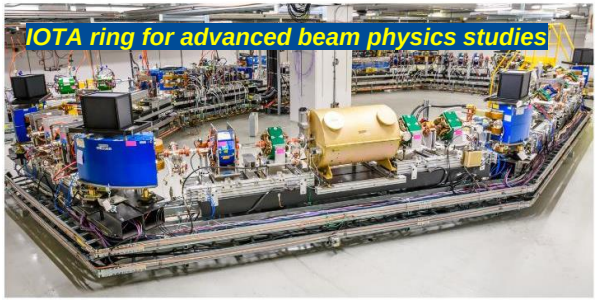
Accelerator S&T Goals

Advance Accelerator Technology and Beam Physics to enable and enhance future accelerators

- **Explore** scientific limits to accelerating gradients and quality factors for future SRF-based accelerators
- **Enable** high field accelerator magnets beyond 15T for high energy future colliders
- **Develop** sustainable targets solutions for Mega-Watt scale proton beams

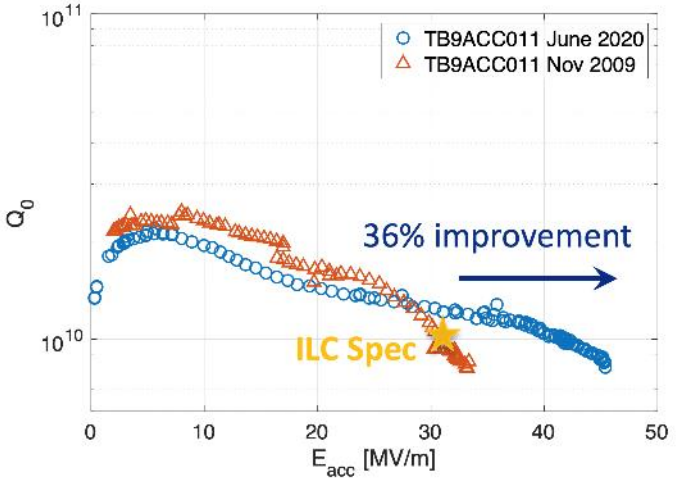
Fermilab is an essential contributor to present and future large accelerators





Research towards an ILC

- Present **ILC** spec 31.5 MV/m
- Fermilab SRF R&D has achieved nearly 50 MV/m and high quality factor ($Q > 10^{10}$)
- Under **US-Japan / ILC Cost Reduction**, FNAL (in collaboration with Jefferson Lab and Cornell) will build a demonstration cryomodule.
- At > 40 MV/m, it will be the world's best performing cryomodule.



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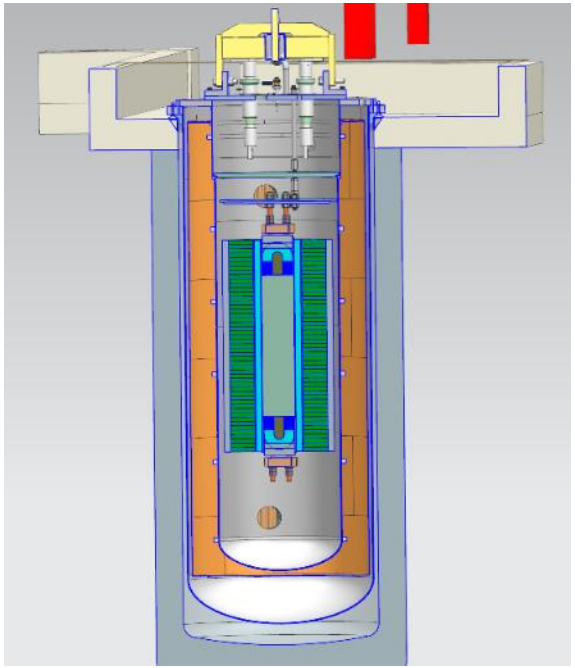
High Field Superconducting Magnets

HEP + FES

- Future high energy hadron colliders (such as **FCC-hh outlined in European Strategy Update**) will require high field magnets.
- Fermilab R&D (within the framework of US-MDP) has produced a “15 T dipole demonstrator”, 1 m long, 60 mm aperture, Nb_3Sn dipole magnet.
- New records established: 14.1 T at 4.5 K, 14.5 T at 1.9 K.
- Nb_3Sn conductor R&D, supported by DOE ECA, has achieved world-leading results with wires surpassing FCC specifications.

High Field Vertical Magnet Test Facility



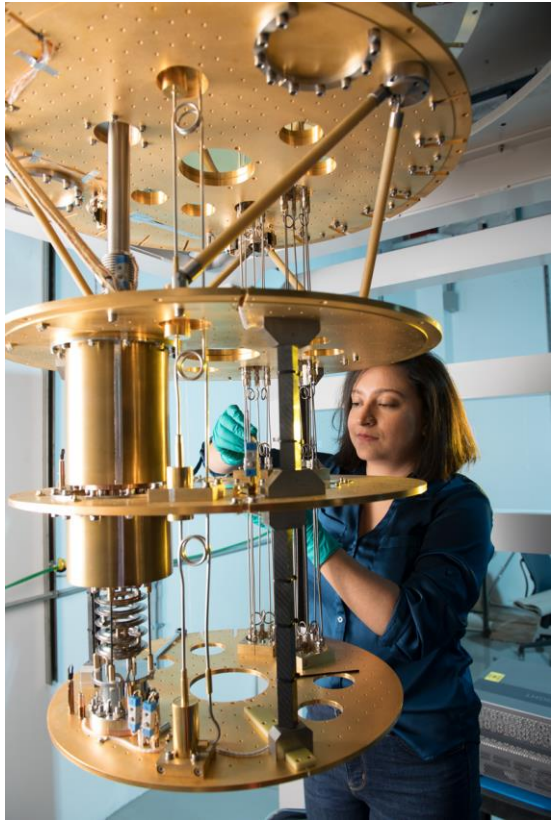
Fermilab Quantum Science and Technology

Highlights of current core program

- Foundational theory and simulations
- R&D for quantum computing systems and quantum sensors
- Quantum experiments
- Quantum collaborators
- Quantum workforce development

Quantum internet blueprint

Fermilab as a national quantum center



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Quantum collaborations with 17 URA universities

HEP + ASCR + BES

- Caltech
- UC Berkeley
- Stanford
- U. Colorado
- Yale
- Georgia Tech
- U. Chicago
- IIT
- U. Illinois Urbana-Champaign
- Northwestern
- Purdue
- Johns Hopkins
- Harvard
- M.I.T.
- U. Washington
- U. Wisconsin
- U. Liverpool

URA UNIVERSITIES RESEARCH ASSOCIATION

Quantum computing for high school students

Ranbel Sun

Anastasia Perry

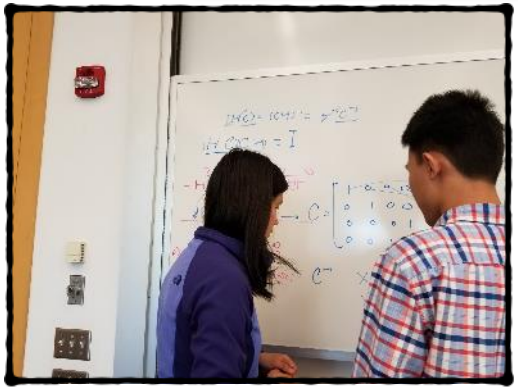
High School Teachers

Ciaran Hughes

Joshua Isaacson

Jessica Turner

Fermilab Scientists



Students Learning Quantum Computing from our course. Left: Quantum Teleportation. Right: C-not gate.

arXiv:2004.07206
arXiv:1905.00282

DOE HEP
QuantISED

Fermilab

Quantum Internet Blueprint

Fermilab-led proposal: DOE National Quantum Initiative Center

With the **Superconducting Quantum Materials and Systems** Center (SQMS), we propose to bring the power of DOE laboratories, together with industry, academia and other federal entities, to “achieve transformational advances in the **major cross-cutting challenge** of understanding and eliminating the decoherence mechanisms in superconducting 2D and 3D devices, with the final goal of enabling construction and deployment of superior quantum systems for computing and sensing.”

Summary

- We are executing the US HEP plan articulated through the P5 process
- The P5 plan top priority in medium time frame is LBNF/DUNE and PIP-II
- We have successfully concluded agreements with many international partners
- Our science program is uniquely high energy physics
  - Quantum S&T and data analytics are naturally synergistic with our program
- Our accelerator technology is making key advancements
  - Required for the HEP future
  - With benefits to many areas of DOE/SC

- We are on a path towards discovery science addressing profound mysteries of the sub-atomic and cosmological universe