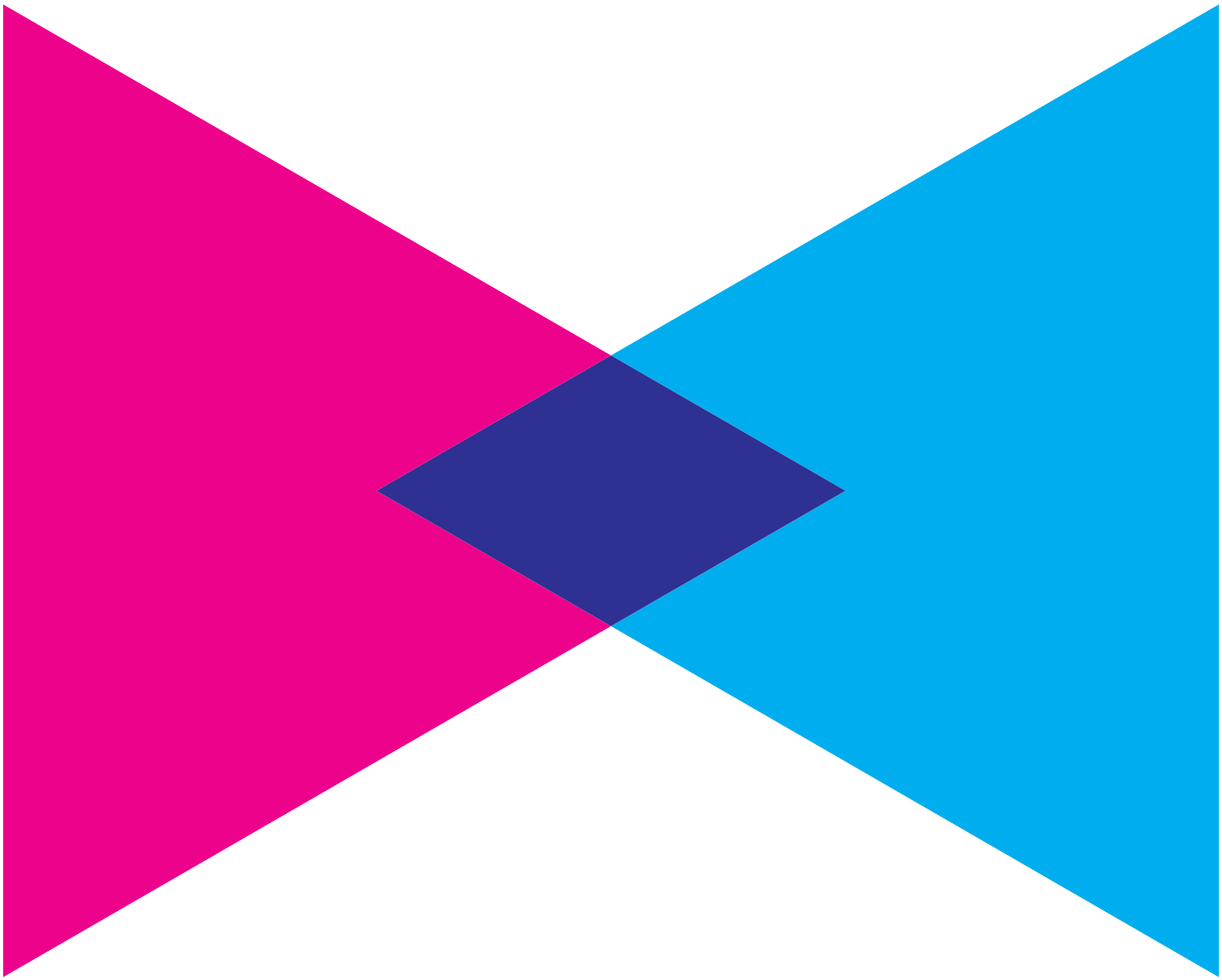
usparticlephysics.org

U.S. Particle Physics



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The U.S. particle physics community asks for your support of the P5 Report's strategic plan by providing FY2026 appropriations that include:

$1.385B for High Energy Physics including at least $360M (26%) for core research, within a budget of $9.5B for the Department of Energy's Office of Scienceand $9.9B for the National Science Foundation,consistent with Congressional authorizations.

This level of funding will enable the U.S. to drive world-leading high energy physics research, advance the highest priority large-scale projects, sustain facility operations, and promote a portfolio of small and medium-sized projects. Specifically, core research funding provides critical support for scientific researchers and students at universities and national laboratories to advance experimental and theoretical research, conduct accelerator and detector R&D, and train the next-generation STEM workforce.

Specifically, this level of funding is needed to advance the major priorities of the P5 strategic plan by:

Restoring and growing core research at universities and national laboratories to maintain U.S. leadership and advance groundbreaking scientific discoveries;

Ramping up construction of world-class science facilities and state-of-the-art instrumentation, including P5's highest priorities—accelerator and detector upgrades at the Large Hadron Collider (LHC), the Long-Baseline Neutrino Facility (LBNF) and the Deep Underground Neutrino Experiment (DUNE), and the Cosmic Microwave Background Stage 4 (CMB-S4) experiment;

Funding operations of experiments and facilities to support the scientific research of thousands of users from national laboratories and academic institutions;

Building the future of high energy physics through focused R&D in accelerators, instrumentation, computing, and theory, as well as cutting-edge research and innovation in emerging technology areas including Quantum Information Science, Artificial Intelligence/Machine Learning, and Microelectronics; and

Expanding workforce and education programs in STEM to attract and invest in the next generation of top domestic and international talent.

Particle Physics Propels U.S. Progress

Particle physicists endeavor to *understand matter, energy, space, and time*—from the *tiniest particles* to the *entire cosmos*. Investment in fundamental research enables the U.S. to champion global collaboration, spearhead scientific breakthroughs, and power innovation.

Exploring the Quantum Universe

America's particle physics research program transforms our understanding of the universe by pursuing some of humankind's most profound questions:

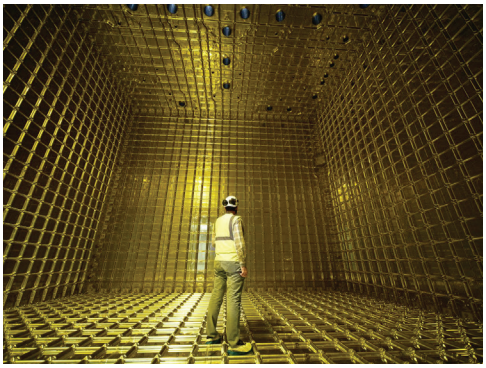
- How did the **universe evolve** into its present form?
- What are the **fundamental building blocks of matter**?

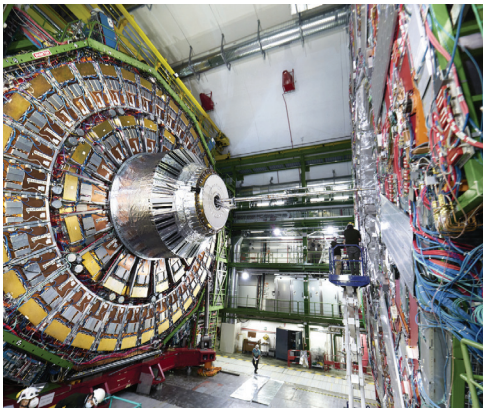
These questions inspire the construction of world-leading facilities, from particle accelerators to telescopes, to illuminate the sweeping connections between nature's smallest and largest structures.

Investing in the Future

Sustained progress in particle physics over the next decade requires continued and amplified investment to:

- Train the **next generation of scientists** and build a **competitive workforce** to steer technological advancement
- Construct critical **technological** and **computational infrastructure** to ensure U.S. leadership in cutting-edge research
- Advance **emerging technologies** and **theoretical frameworks** to facilitate cross-disciplinary synergies with industry





Driving Advancements in Technology R&D

The U.S. particle physics community comprises a network of scientists, engineers, technicians, and students whose work continues to galvanize innovation across a wide range of sectors:

- **Medicine**: Improve diagnostics & treatment of disease
- **Security**: Sharpen nuclear monitoring & cyberinfrastructure
- **Energy**: Strengthen breakthroughs in nuclear fusion
- **Computing**: Enhance quantum systems & artificial intelligence
- **Industry**: Promote manufacturing & microelectronics partnerships
- **Geology + Archeology**: Study natural & manmade structures

The U.S. particle physics community's vision is guided by intertwined science drivers—*Deciphering the Quantum Realm*, *Illuminating the Hidden Universe*, and *Exploring New Paradigms of Physics*—that represent the most promising avenues of investigation.

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Exploring the Quantum Universe

Pathways to Innovation and Discovery in Particle Physics
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U.S. particle physics advances the frontiers of discovery science, builds and trains a highly skilled technical workforce, and advances U.S. leadership worldwide.

The 2023 P5 report provides the long-term strategy and priorities for U.S. investments in particle physics for the next 10 years within a 20-year vision.

The top priorities in 2025 are to advance current construction projects, support operations of ongoing experiments, and strengthen support for research at universities and national laboratories to maximize the opportunities for scientific discoveries.

Support for big data analysis, innovative instrumentation, a vibrant theory program, and future accelerator development is essential to maintain U.S. leadership and train the next generation of scientists. U.S. particle physics also plays a key role in national initiatives in microelectronics, Artificial Intelligence and Machine Learning, and quantum information science.

It is critical to complete construction and deliver science from the following projects:

High-Luminosity Large Hadron Collider (HL-LHC) is an accelerator and detector upgrade to continue the highly successful LHC program and bilateral partnership with CERN. This will allow for precise measurements of the Higgs boson and its interactions. Searches for new physics using state-of-the-art machine learning techniques at the highest-ever center-of-mass energy will broaden our understanding of fundamental physics.

Deep Underground Neutrino Experiment (DUNE) is the first U.S.-hosted world-leading international science mega-project. It will determine the fundamental properties of the mysterious neutrinos that permeate the cosmos. DUNE will be powered by the superconducting PIP-II linear accelerator at Fermilab.

Vera C. Rubin Observatory is a major new telescope and camera nearing completion in Chile. Its Legacy Survey of Space and Time (LSST) will study cosmic evolution and other fundamental astrophysical questions.

CMB-S4 is a next-generation cosmic microwave background (CMB) experiment with an array of telescopes in the Chilean Atacama Desert. It will observe fingerprints from the earliest moments of the Universe to understand its origins.

These carefully chosen investments will enable a steady stream of exciting new results for many years to come and will maintain U.S. leadership in key areas.

Particle Physics in the United States

Particle physics is both global and local. Scientists, engineers, and technicians at over 200 universities, institutes, and laboratories throughout the U.S. are working in partnership with their international colleagues to build high-tech tools and components and conduct scientific research. Particle physics excels at building a highly-skilled technical workforce across the country by training and educating the next generation of innovators. Particle physics activities in the U.S. attract leading scientists from around the world.

The P5 strategy continues to be very successful. The 2023 P5 report builds upon these successes and charts the course to a new era of discovery, innovation, and U.S. leadership for the next decade and beyond.

Recent Science Results

The **ATLAS** and **CMS** collaborations at the **LHC** have each produced more than 1,300 refereed publications as they continue to probe the fundamental properties of the Higgs boson and expand their reach for new particles, forces of nature, and physical principles. Among dozens of examples, they have probed very rare decays of the Higgs boson, observed the simultaneous production of four top quarks, and detected quantum entanglement in top-quark pairs at the highest energies.

The **LHCb** experiment discovered new configurations of quarks, measured differences between the properties of matter and antimatter, and reported evidence for an intriguing deviation from the expectation in the properties of leptons.

The **Dark Energy Survey** collaboration has published cosmological results from supernovae and the baryonic acoustic oscillations using their final data. Together they can set strong constraints on the expansion history of the Universe. .

The **Dark Energy Spectroscopic Instrument (DESI)** has mapped over 39 million galaxies and quasars, creating the largest ever 3D map of the Universe. The third-year DESI results, accompanied by a publicly available data release, provide the most precise dark energy measurements ever made and indicate that dark energy may vary over cosmic time.

The **IceCube** experiment in Antarctica used an AI model to detect seven high-energy tau neutrino interactions of astrophysical origin.

The **NOvA** and **T2K** experiments, based at Fermilab and in Japan respectively, have produced their first joint analysis of long-baseline neutrino oscillation. The new results provide insight into the mass ordering and flavor symmetry of neutrinos.

The **COHERENT** collaboration measured for the first time the coherent scattering of neutrinos with germanium.

The **LUX-ZEPLIN (LZ)** dark matter experiment in South Dakota has published new results, providing world-leading constraints on the particle identity of dark matter across a vast range of mass scales, and promising greater sensitivity with continued data collection.

Program Advances and Milestones

The **CMS and ATLAS upgrades**, built at U.S. institutions, have begun arriving at CERN for assembly. The first two of the ten **HL-LHC** focusing magnets are delivered to CERN. They will be used to demonstrate the capabilities of the new superconductor technologies to provide the high luminosity for the HL-LHC and beyond, towards much higher energy future colliders.

The **Long Baseline Neutrino Facility (LBNF)** construction is on schedule. Excavation of the caverns has been completed in South Dakota and work on outfitting the caverns for installation of the Far Detector (FD) has started. Cryostat components continue to be delivered for installation and deployment in the caverns. Fermilab will construct a new beamline and detector hall to host the Near Detector (ND). This new beamline, and the combination of the ND and FD will be essential components of **Deep Underground Neutrino Experiment (DUNE)**, which is slated to take first data at the end of this decade.

The **LSST Camera at the Vera C. Rubin Observatory**, the world's largest camera for astrophysics has been installed in Chile. Commissioning of the three-ton, 3.2-billion-pixel camera begins in summer 2025.

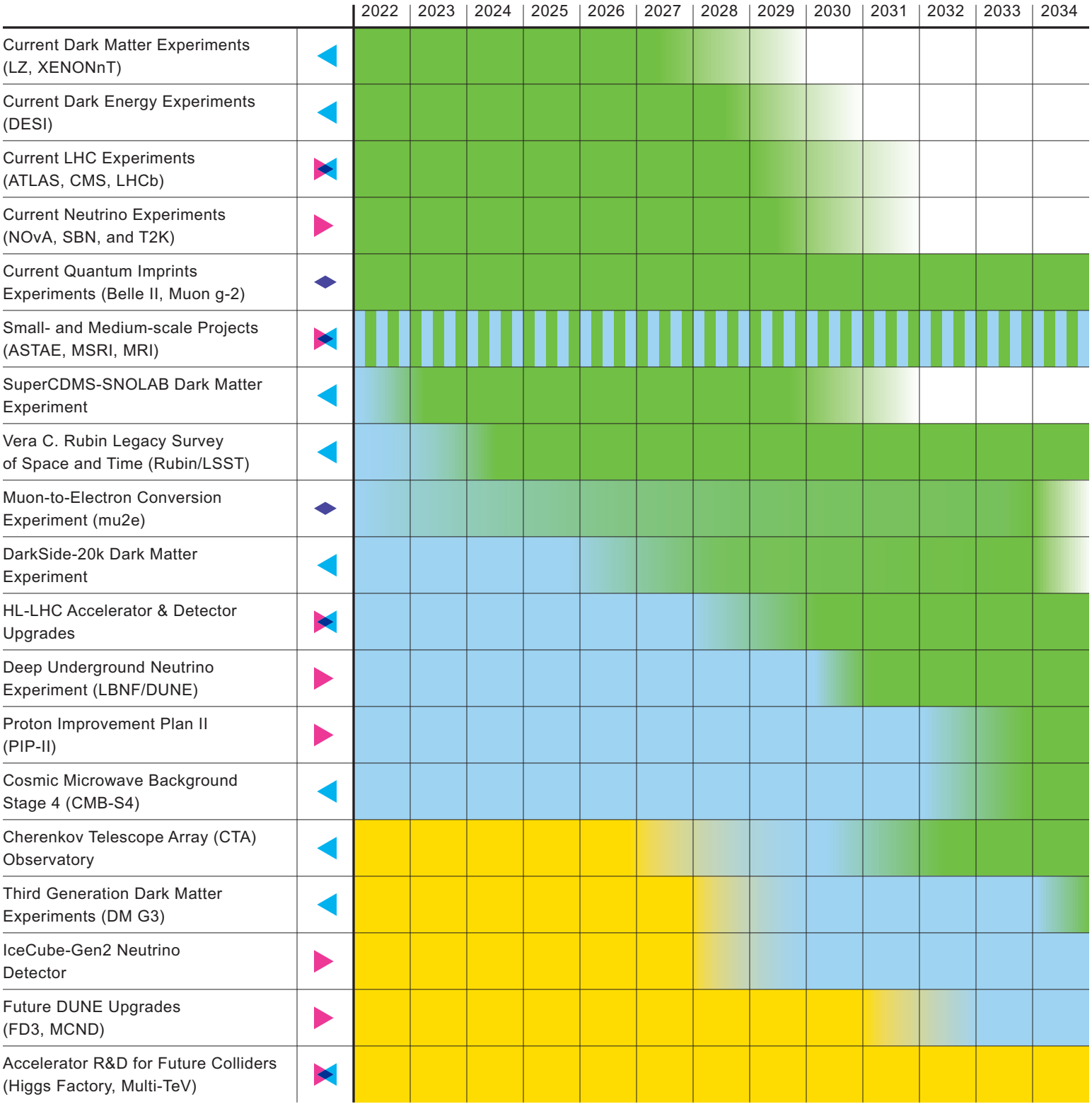
The **Short Baseline Near Detector (SBND)** at Fermilab has been filled with liquid argon and has detected its first neutrinos.

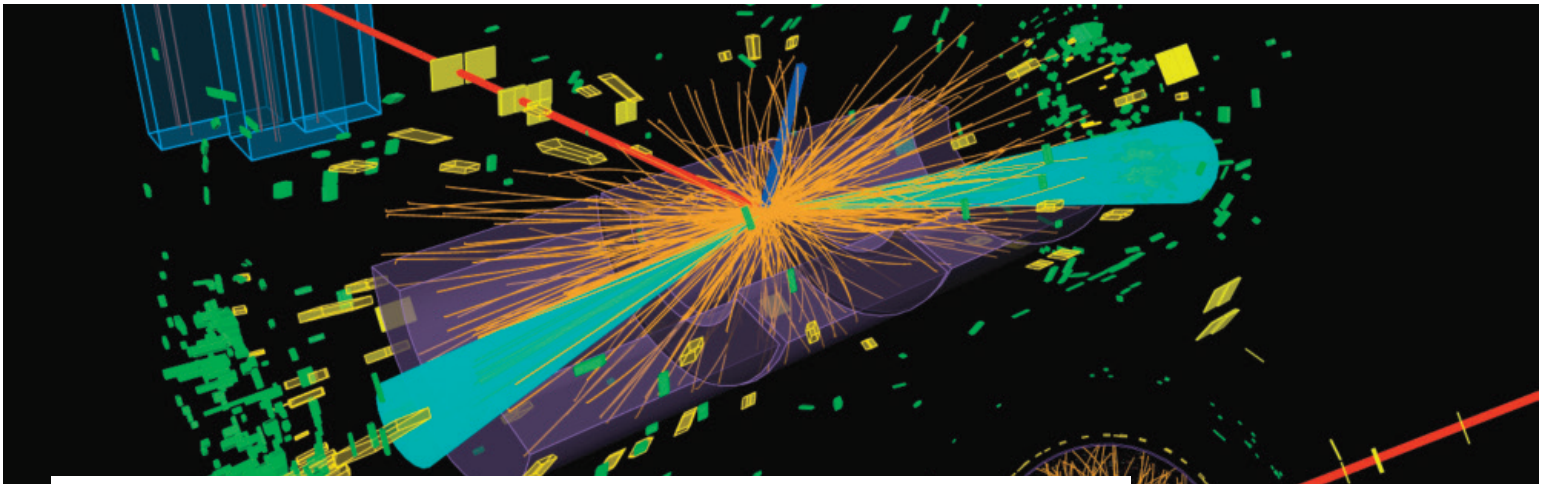
All four **SuperCDMS** towers have been delivered from SLAC to SNOLAB in Canada. Construction is projected to finish in mid-2025, with commissioning through the end of 2025.

Theoretical physicists have discovered connections among quantum entanglement, information, and gravity, shedding important new light on the black hole paradox pointed out by the late Stephen Hawking, and suggesting novel ideas about the emergence of spacetime. Theorists are also active in the use of AI/ML and developing QIS techniques to simulate the quantum world of elementary particles, as well as devising new ways to use quantum sensors in novel searches for dark matter.

Particle Physics Experiments Timeline

Phase of Experiment	Science Themes	Science Drivers
Operation & Analysis	Decipher the Quantum Realm	Neutrinos, Higgs Boson
Fabrication/Construction	Illuminate the Invisible Universe	Dark Matter, Cosmic Evolution
Conceptual & Technical Design	Explore New Paradigms in Physics	New Particles, New Phenomena





Particle Physicists

Advance Artificial Intelligence

As physicists, we push the boundaries of AI by using cutting-edge techniques to:

- Operate complex particle accelerators
- Enhance rapid image processing
- Minimize computational resources
- Train algorithms to filter unreliable information
- Collaborate with industry leaders
- Expand ultrafast data processing

Dr. Nhan Tran, Fermilab developing new high speed computing techniques using AI.

Train an AI-adept workforce

"AI is important because it can help you discover things your brain and other techniques can't… Industry needs this expertise, and I've already worked with ***Boeing, Lockheed Martin, and companies in the energy sector****."*

Sandra Biedron, University of New Mexico and Element Aero

"At Tesla, I transformed enormous data sets into detailed road maps for self-driving cars and at DeepMind, I am building AI systems that imagine and plan. ***My experience in particle physics trained me to tackle these complex problems*** *while dealing with the noisy and uncertain data of the real world."*

Alex Mott, DeepMind

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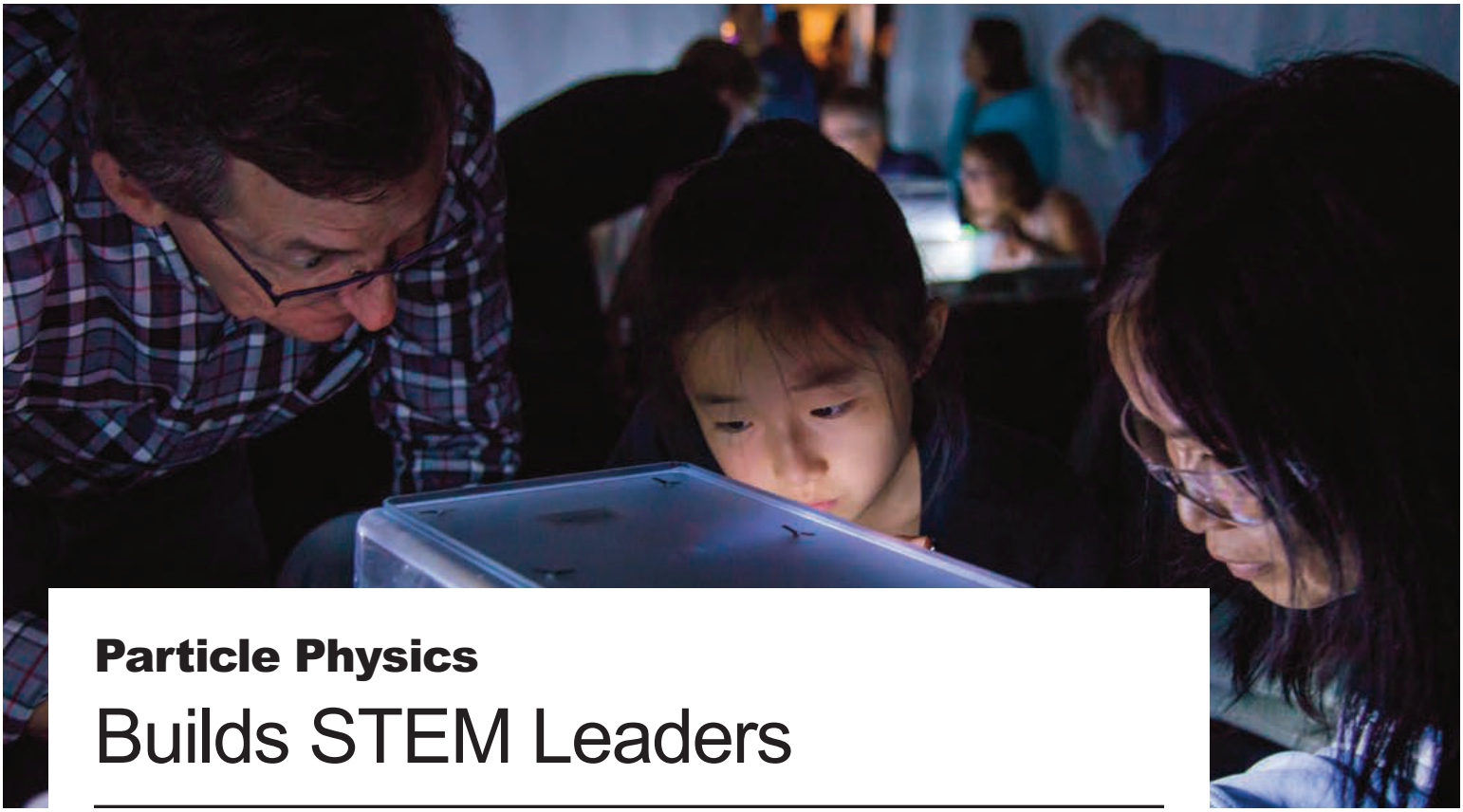

Particle Physics

Builds STEM Leaders

Our public engagement programs,reaching tens of thousands of people every year, promote interest in STEM careers and demonstrate how science makes a difference in our lives.

"SAGE summer camps *introduce [high schoolers] to the work and daily life of US National Laboratories scientists and engineers."*
Giulia Lanza, SLAC National Accelerator Laboratory

"The Big Bang Science Fair *caters to ages 3 to 99."*
Meenakshi Narain, Brown University

"As part of the ***QuarkNet program****, we invite high school students to do a crash-course in particle physics."*
Joe Haley, Oklahoma State University

We develop our students' analytical and technical skills, enabling them to excel in all industries.

Their contributions spur innovation in technology, energy, medicine, artificial intelligence, and quantum computing.

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Particle Physicists

Broaden Research Opportunities

Opening Doors for Community College Students

Robert Zill worked on sensors for the IceCube Neutrino Observatory in the South Pole and connected with a global community of researchers—all as a student from **College of DuPage, a public community college** in Illinois.

Immersive Internships for Exceptional Undergraduates

*"I got to **collaborate with different teams**... I'm proud of myself because I finished something, and now I **can see myself finishing school and not giving up**."*

Jordan Glover, Tougaloo College, USCMS PURSUE Program Student

*"My physics professor recruited me for a **[NSF] Research Experience for Undergraduates** program. The adventure of a real summer job in research **inspired me to pursue science as a career**."*

Michelle Stancari, Senior Scientist, Fermilab

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Particle Physicists

Bolster National Security

Advanced Cargo Screening—Particle physics detector technology improves homeland security by enabling advanced cargo screening.

Investigations inside Nuclear Reactors—U.S. scientists helped create a particle detector system to safely look inside the nuclear reactors in Fukushima after the earthquake and tsunami in Japan.

Remote Monitoring of Nuclear Reactors—The PROSPECT, Chandler, and MAD neutrino detectors in the U.S. are demonstrating technology for the monitoring of nuclear reactors, supporting nonproliferation efforts.

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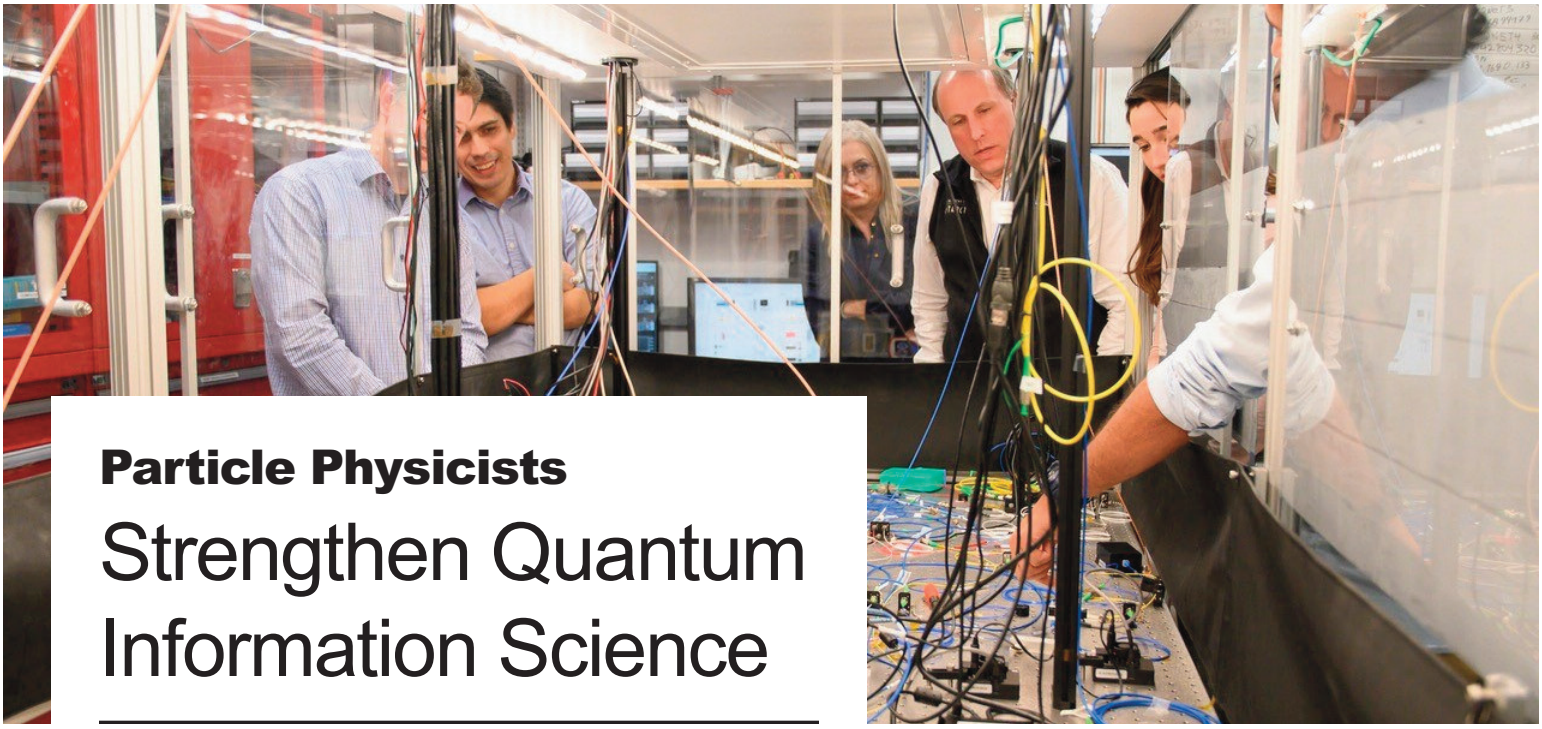
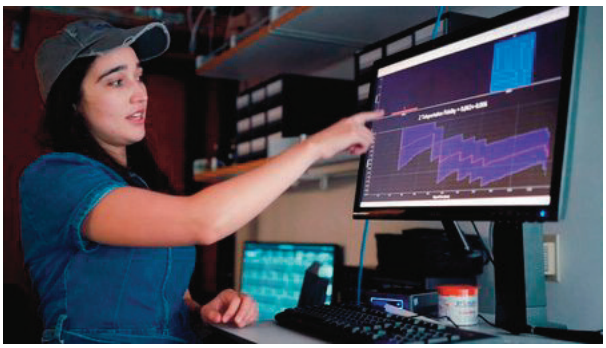


Particle Physicists

Strengthen Quantum Information Science

Demonstration of high-fidelity quantum teleportation on a quantum network.

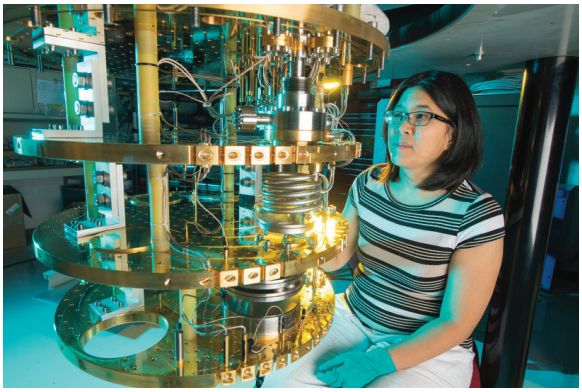
Quantum Information Science (QIS)—A new field of study that combines quantum mechanics and information theory to study processing, analyzing, and transmission of information.



Caltech graduate student Samantha Davis analyzes quantum teleportation data.

Particle physicists develop sensors to detect single particles and build the world's largest superconducting systems.

Physicist Lauren Hsu works on a dilution refrigerator for quantum sensors.



Particle physicists achieved the high-fidelity teleportation of light-particle "qubits" via a 27-mile quantum network, using sensors originally developed for cosmological observations.

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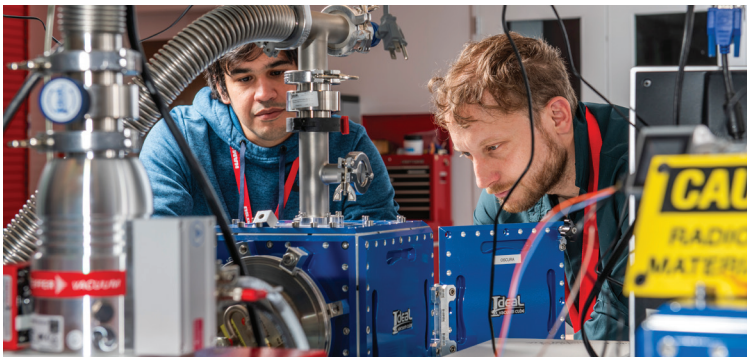
Particle Physicists

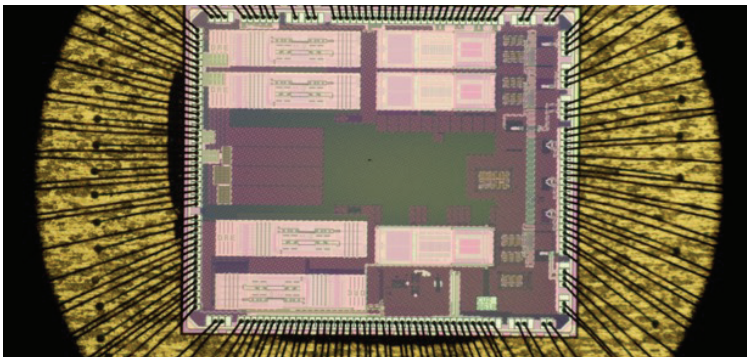
Spurs Microelectronics Innovation

Experimental particle physics is advancing our understanding of the universe while creating technologies with real-world impacts across fields like **communication, computing, and weather science**.

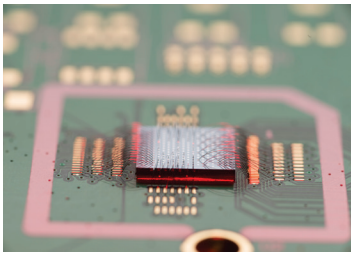


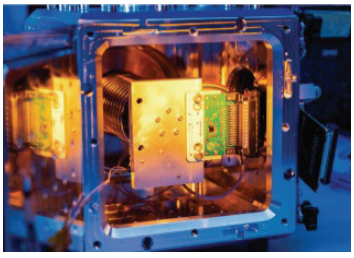
The particle physics community trains students in **industry-standard tools** and workflows.

Microelectronics developed here have direct applications to **avionics, space travel, medicine, and the military**.



Analog to digital converter known as COLUTA —Produced for high speed data transmission in extreme radiation environments.





National lab particle-beam test facilities are essential for designing and testing radiation-tolerant chips for **particle physics, satellites, and space travel**.

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