Building for Discovery

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

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The P5 Report provides the long-term strategy and priorities for U.S. investments in particle physics.

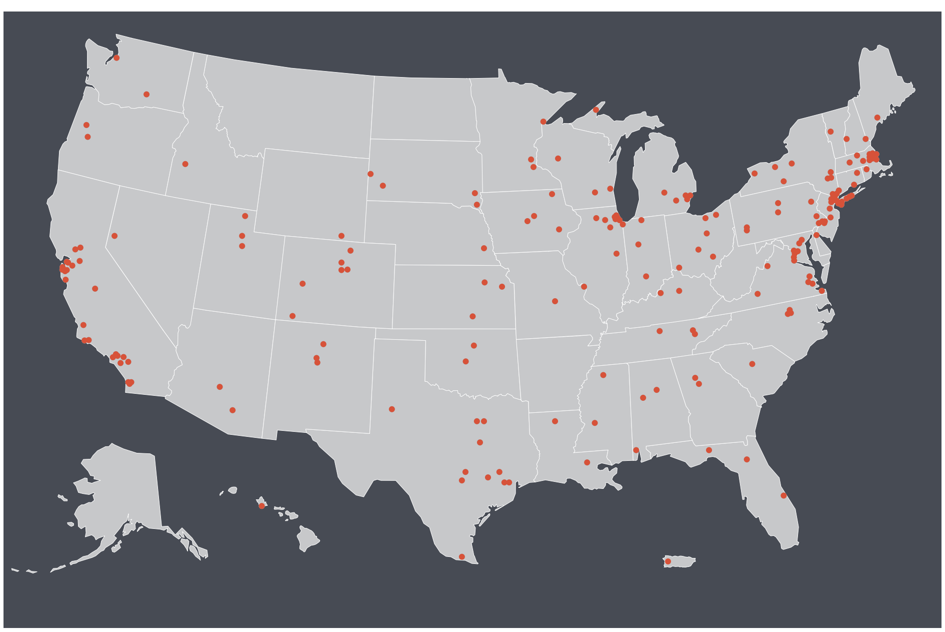
The top three priorities in 2023

Strengthen support for particle physics research at universities and national laboratories, which includes data analysis, R&D, design of new experiments, and a vibrant theory program. As emphasized in the P5 Report, these activities are essential for the success of the field. They are crucial for extracting scientific knowledge from all the great new data, developing new methods and ideas, maintaining U.S. leadership, and training the next generation of scientists and innovators.

Advance the High-Luminosity Large Hadron Collider (HL-LHC) accelerator and ATLAS and CMS detector upgrade projects on schedule, continuing the highly successful LHC program and bilateral partnership with CERN.

Advance the Long-Baseline Neutrino Facility (LBNF), Deep Underground Neutrino Experiment (DUNE), and Proton Improvement Plan-II (PIP-II), working with international partners on the design, prototypes, initial site construction, and long-lead procurements.

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 is both global and local. Scientists, engineers, and technicians at 190 universities, institutes, and laboratories throughout the U.S. are working in partnership with their international colleagues to build high-tech tools and components, conduct scientific research, and train and educate the next generation of innovators. Valuing equity, diversity, and inclusion, the field is committed to increasing participation of underrepresented groups. Particle physics activities in the U.S. attract some of the best scientists from around the world.

The P5 strategy continues to be very successful. Even with extraordinary challenges due to COVID-19, there was great progress.

Recent results

Researchers at **Fermilab** demonstrated an important new technique, called optical stochastic cooling, to make **more intense particle beams**.

The **LZ dark matter detector** in South Dakota published its first results, providing important new constraints on the particle identity of dark matter and promising greater sensitivity with continued data taking.

The LHC experiments reported many important and precise results. The remarkably productive ATLAS and CMS experiments have each produced more than 1,000 refereed publications. The advances in precision are represented well by the new measurements of fundamental properties of **Higgs boson** decays that provide a sensitive tool for discovery of new physics. The new precision measurement of the W-boson mass by CDF at Fermilab further motivates precision studies at the LHC. The **LHCb experiment** also discovered new configurations of quarks, measured the rate of antimatter production in proton collisions, and reported an intriguing deviation from expectation in B-meson decays.

Theoretical physicists have discovered connections among quantum entanglement, information, and gravity, suggesting novel ideas about the emergence of spacetime.

The **MicroBooNE** and **MINERvA neutrino experiments at Fermilab each published new results**: MicroBooNE placed limits on additional types of exotic neutrinos, and MINERvA probed protons using antineutrinos. The KamLAND-ZEN collaboration published an important new bound on whether neutrinos can be their own antiparticles.

Program advances in 2022

Building upon the historic bilateral U.S.-CERN agreements, U.S. and CERN scientists successfully continued their cooperative partnership at the LHC and the international neutrino program hosted by Fermilab. The LHC experiments, ATLAS and CMS, successfully passed their high-luminosity upgrade CD-2/3a reviews. The LHC will restart operations in spring 2023 after technical improvements during the winter.

The **LBNF/DUNE-US** project successfully passed a CD-1RR review as well as CD-2/3 reviews to complete excavation of underground caverns, now well past 50% complete, and to outfit the completed caverns. Mass-production of components for the first **DUNE** far detector has started. So far, government-to-government agreements with 10 countries have been signed for LBNF/DUNE, PIP-II, and the Short Baseline Neutrino program at Fermilab, with more in progress. The PIP-II accelerator project, needed for reaching LBNF physics goals, passed its DOE CD-3 milestone, opening the way to construction, which is expected to be complete in 2028.

The **Vera C. Rubin/LSST Camera** is now fully assembled at SLAC and is on track for delivery to the Observatory in the first half of 2023. The LSSTCam Project received the DOE Secretarial Achievement Award. **The Dark Energy Spectroscopic Instrument (DESI)** continued its five-year survey, collecting 18 million galaxy and quasar redshifts so far, and is ahead of schedule.

The next-generation cosmic microwave background facility, CMB-S4, which was ranked highly in both the NAS Decadal Survey of Astronomy & Astrophysics and the 2014 P5 report, is progressing. CMB measurements uniquely probe **physics of the early universe**, at energies far beyond what can be studied at earth-bound accelerators, and can also reveal fundamental neutrino properties.

Looking forward

All eyes are on the LHC, as its sensitivity to new physics will continue to improve through vastly greater data volumes and new deep-learning data analysis methods. The experiments will extend their discovery reach and probe the Higgs boson's properties with ever greater precision for many years to come. Despite COVID and funding constraints, the HL-LHC upgrade projects are progressing. The LHC continues to break energy and luminosity records.

Eagerly anticipated new data from operating experiments will advance the understanding of the intertwined Science Drivers identified in the P5 Report. At the LHC, the accelerator is on track to resume operations this spring for data-taking by the successfully upgraded experiments. Looking upward, the first data release from the DESI dark energy spectroscopic survey is expected in 2023.

Particle physicists are expanding efforts to develop and apply artificial intelligence (AI) techniques to the operation of accelerators and experiments, data analysis, and simulations, opening new avenues for scientific discovery.

Theoretical and experimental particle physicists are advancing Quantum Information Science (QIS), providing solutions to problems in computation, data analysis, sensors, and simulations, with several notable recent results.

The particle physics theory community will continue to play key roles in interpreting results from current experiments, motivating future experiments, and pursuing answers to the deepest questions.

Looking beyond the current P5 horizon, and guided by new results, U.S. particle physicists engaged in the Snowmass community planning process, in which opportunities in all areas of the field were discussed in depth. The output of the process is available as essential input to the new P5, which is now developing the strategic plan for 2024 and beyond. To inform choices, the U.S. is also working with partners worldwide on the development of concepts for facilities that could be hosted in the U.S. and abroad.

U.S. researchers are pursuing R&D on advanced technologies to enable future generations of accelerators and detectors with a wide variety of applications in science, medicine, and industry.