Building for Discovery

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

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The P5 Report provides the strategy and priorities for U.S. investments in particle physics for the coming decade.

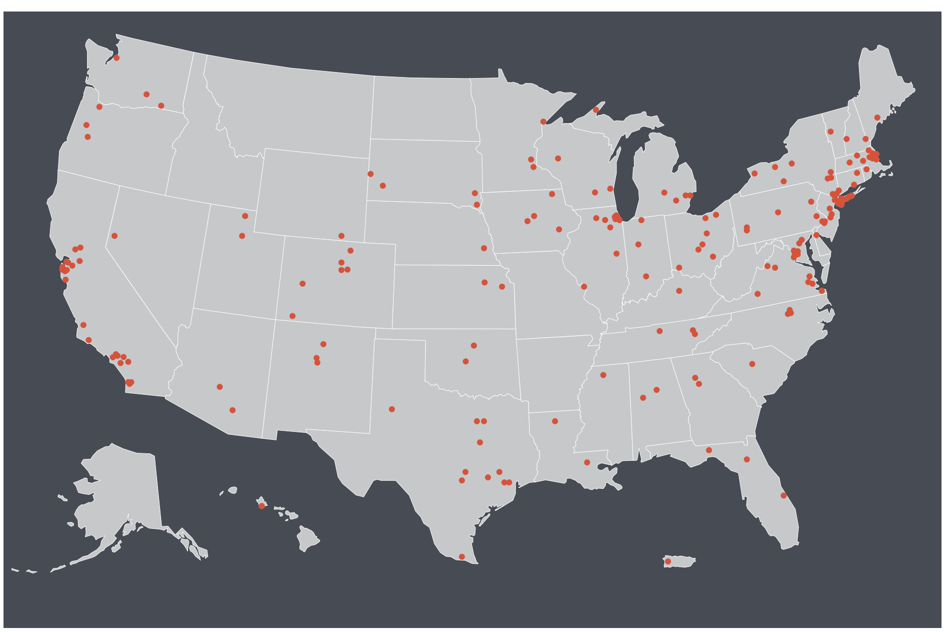
The top three priorities in 2021

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 more than 175 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 has been very successful. Even with extraordinary challenges due to COVID-19, there was great progress.

Recent results

The LHC experiments reported many important and precise results. The remarkably productive ATLAS and CMS experiments have each produced about 1,000 refereed publications, including the recent evidence of **Higgs boson** decays to muon pairs and other processes that test the foundations of the underlying theory. The LHCb experiment also published many new results, including studies of B-meson processes that are sensitive to **new physics**.

Theoretical physicists have gained insight into how evaporating black holes can radiate their quantum information, suggesting new aspects of **quantum gravity**. They also have proposed new candidates for the **dark matter** and new ways to search for them.

The **High-Altitude Water Cherenkov (HAWC) Observatory** detected the highest energy cosmic gamma ray ever seen. Such observations can be used to test fundamental symmetries and to constrain quantum gravity models.

Program advances in 2020

Building upon the historic 2015 and 2017 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. ProtoDUNE published results demonstrating that the design meets the requirements needed by the LBNF/DUNE far detector in South Dakota for neutrinos produced at Fermilab.

Important advances toward the next generation of colliders were achieved, including new world records in high-gradient superconducting acceleration technology and in high-field superconducting accelerator steering magnets.

The **DESI** and **Vera C. Rubin/LSST Camera cosmic survey projects** have successfully transitioned from construction to commissioning and operations, as has the **LZ dark matter experiment**.

The next-generation cosmic microwave background facility, CMB-S4, moved forward with the selection of LBNL as the host laboratory. CMB measurements uniquely probe physics of the early Universe at energies well beyond those of earth-bound accelerators and can also reveal 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. The HL-LHC upgrade projects are on track.

Eagerly anticipated new data from operating experiments will advance the understanding of the intertwined Science Drivers identified in the P5 Report. In addition, this year the Dark Energy Spectroscopic Instrument (DESI) is starting operations, and the first results of the Muon g-2 experiment are expected to provide the most precise experimental measurement of the muon's magnetic moment.

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.

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, the US has begun the next Snowmass community process, in which the opportunities in all areas of the field are discussed in depth. To inform choices, the US is also working with partners worldwide on development of concepts for facilities that could be hosted here and abroad. In addition to the well-studied International Linear Collider (ILC) in Japan, there are proposed facilities such as the Future Circular Collider (FCC) at CERN, which is part of the recently completed European Strategy for particle physics.

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.