Building for Discovery

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

Report of the Particle Physics Project Prioritization Panel (P5)

The U.S. particle physics community has just updated its vision for the future. The P5 report presents a strategy for the next decade and beyond that enables discovery and maintains our position as a global leader through specific investments by the Department of Energy's Office of Science and the National Science Foundation Directorate for Mathematical and Physical Sciences.

Particle physics is a highly successful, discovery-driven science. It explores the fundamental constituents of matter and energy, and it reveals the profound connections underlying everything we see, including the smallest and the largest structures in the Universe. Earlier investments have been rewarded with recent fundamental discoveries, and upcoming opportunities will push into new territory. Particle physics inspires young people to engage with science.

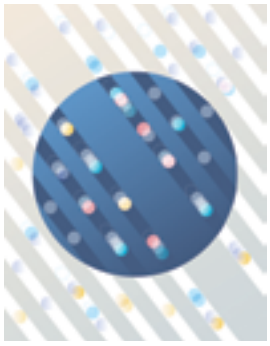
Particle physics is global. To address the most pressing scientific questions and maintain its status as a global leader, the U.S. must both host a unique, world-class facility and be a partner on the highest priority facilities hosted elsewhere.

Choices were required. The updated strategy recommends investments in the best opportunities, chosen from a large number of excellent options, in order to have the biggest impact and make the most efficient use of resources over the coming decade.

Five intertwined scientific Drivers were distilled from the results of a yearlong community-wide study:

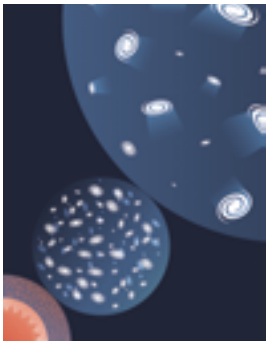
- Use the Higgs boson as a new tool for discovery
- Pursue the physics associated with neutrino mass
- Identify the new physics of dark matter
- Understand cosmic acceleration: dark energy and inflation
- Explore the unknown: new particles, interactions, and physical principles

Higgs boson



Neutrino mass

Dark matter



Cosmic acceleration

Explore the unknown

The U.S. particle physics program is poised to move forward into the next era of discovery.

The P5 report recommends a prioritized and time-ordered list of experiments to address the five science Drivers optimally. These opportunities are at the small, medium, and large investment scales that, together, produce a continuous flow of major scientific results throughout a twenty-year timeframe.

- Large projects, in time order, include the Muon g-2 and Muon-to-electron Conversion (Mu2e) experiments at Fermilab, strong collaboration in the high-luminosity upgrades to the Large Hadron Collider (HL-LHC), and a U.S.-hosted Long Baseline Neutrino Facility (LBNF) that receives the world's highest intensity neutrino beam from an improved accelerator complex (PIP-II) at Fermilab.
- U.S. involvement in a Japanese-hosted International Linear Collider (ILC), should it proceed, with stronger participation in more favorable budget scenarios.
- Areas with clear U.S. leadership in which investments in medium- and small-scale experiments have great promise for near-term discovery include dark matter direct detection, the Large Synoptic Survey Telescope (LSST), the Dark Energy Spectroscopic Instrument (DESI), cosmic microwave background (CMB) experiments, short-baseline neutrino experiments, and a portfolio of small projects.
- Specific investments in particle accelerator, instrumentation, and computing research and development are required to support the program and to ensure the long-term productivity of the field.

Several significant changes in direction are recommended:

- Increase the fraction of the budget devoted to construction of new facilities.
- Reformulate the long-baseline neutrino program as an internationally designed, coordinated, and funded program with Fermilab as host.
- Redirect specific activities and efforts at Fermilab to the PIP-II program of improvements to the accelerator complex, which will provide proton beams with power greater than one megawatt by the time of first operation of the new long-baseline neutrino facility.
- Increase the planned investment in second-generation dark matter direct detection experiments.
- Increase particle physics funding of CMB research and projects in the context of continued multiagency partnerships.
- Re-align activities in accelerator R&D with the new strategic plan, and emphasize capabilities that will enable creating future-generation accelerators at dramatically lower cost.

Small changes in yearly budgets have large impacts on the timeline and capability of the U.S. particle physics program. A very large return on investment is ensured by the relatively small increment in funding between the constrained budget scenarios given in the P5 charge:

- A small limited-time funding increment to ensure support of the Dark Energy Spectroscopic Instrument (DESI) would yield scientific returns with high impact.
- World-leading accelerator and instrumentation development research would be retained.
- U.S. research capability would be maintained, including a thriving theory program.
- The Muon-to-electron Experiment (Mu2e) at Fermilab would be completed on time.
- The long-baseline neutrino program would proceed without delays.
- The third-generation dark matter direct detection capabilities would be fully developed on time.

The lowest budget scenario given in the P5 charge is precarious. It is close to the point beyond which the U.S. would not be capable of hosting a large project while maintaining the other core program components that ensure mission success. Without this capability, the U.S. would lose its position as a global leader in this field, and highly productive international relationships would be fundamentally altered.

High-priority options for additional investments beyond our constrained scenarios are identified:

- Expand accelerator R&D to enable very high-energy future machines at lower cost, and likely provide benefits beyond particle physics.
- Play world-leading roles in the ILC detector program and provide critical accelerator components, should the ILC proceed in Japan.
- Host a large water-based neutrino detector to complement the LBNF liquid-argon detector and unify the global long-baseline neutrino community around the world's highest intensity neutrino beam provided by Fermilab.

For more information on P5 or to download a PDF copy of the report, visit usparticlephysics.org/p5

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