Briefing to Astro2020 about the Particle Physics Project Prioritization Panel (P5)

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5 September 2019

Outline

- There is far more relevant information than can be presented here. Selected topics represent an educated guess what you will find useful.
  - More information in backup. Time for discussion.
  - Will summarize the main messages, but please read the report.
    - The report is deliberately brief.
  - Combination of official slides and my personal observations (clearly marked).

"*It is very difficult to remember that events now in the past were once far in the future.*"

- Frederic William Maitland

Acknowledgements & Thanks

- Our community
- The P5 Panel
  - Wisdom and devotion
- Andy Lankford (UCI, was HEPAP Chair)
- DOE HEP and NSF PHY
  - Guidance and trust
  - Michael Cooke (DOE HEP) provided continuous, invaluable help in producing messaging materials and ensuring clear communications.

P5 Panel Members

- P5 included mix of Laboratory and University, U.S. and international scientists, with complementary expertise

- **Steve Ritz, *chair*** *University of California, Santa Cruz*
- **Hiroaki Aihara** *University of Tokyo*
- **Martin Breidenbach** *SLAC National Accelerator Laboratory*
- **Bob Cousins** *University of California, Los Angeles*
- **André de Gouvêa** *Northwestern University*
- **Marcel Demarteau** *Argonne National Laboratory*
- **Scott Dodelson** *Fermi National Accelerator Laboratory and University of Chicago*
- **Jonathan L. Feng** *University of California, Irvine*
- **Bonnie Fleming** *Yale University*
- **Fabiola Gianotti** *European Organization for Nuclear Research (CERN)*
- **Francis Halzen** *University of Wisconsin-Madison*
- **JoAnne Hewett** *SLAC National Accelerator Laboratory*
- **Wim Leemans** *Lawrence Berkeley National Laboratory*
- **Joe Lykken** *Fermi National Accelerator Laboratory*
- **Dan McKinsey** *Yale University*
- **Lia Merminga** *TRIUMF*
- **Toshinori Mori** *University of Tokyo*
- **Tatsuya Nakada** *Swiss Federal Institute of Technology in Lausanne (EPFL)*
- **Steve Peggs** *Brookhaven National Laboratory*
- **Saul Perlmutter** *University of California, Berkeley*
- **Kevin Pitts** *University of Illinois at Urbana-Champaign*
- **Kate Scholberg** *Duke University*
- **Rick van Kooten** *Indiana University*
- **Mark Wise** *California Institute of Technology*
- **Andy Lankford, *ex officio*** *University of California, Irvine*

Strategic Plan for U.S. Particle Physics

- **Charge: A strategic plan, executable over 10 years, in the context of a 20-year global vision**
- US community has come together to make a plan.
  - Driven by the science
  - Meets fiscal constraints
  - Considers the global context
  - Resolves key issues for the field
  - Provides a continuous flow of results while making essential investments for the future

U.S. Strategy in High Energy Physics

- The global vision presented in the 2014 Particle Physics Project Prioritization Panel (P5) report is the culmination of years of effort by the U.S. particle physics community
  - 2012 – 2013: Scientific community organized year-long planning exercise (“Snowmass”)
  - 2013 – 2014: U.S. High Energy Physics Advisory Panel convened P5 to develop a plan to be executed over a ten-year timescale in the context of a 20-year global vision for the field.

Snowmass Community Process

- Organized by The Division of Particles and Fields of the American Physical Society
- Designed to address the questions the particle physics community wishes to answer over the next two decades and methods to answer them
  - **Did not prioritize activities**; aim was to ask and answer hard questions
  - Supported inter-frontier discussions to ensure addressing the cross-cutting nature of the physics
    - **Subgroups**: Intensity Frontier; Energy Frontier; Cosmic Frontier; Theory; Accelerator Capabilities; Underground Laboratory Capabilities; Instrumentation; Computing; Communication, Education, and Outreach
  - Produced 358 page resource book that conveyed the health and diversity of the U.S. program in a global context
    - http://www.slac.stanford.edu/econf/C1307292/
  - **Community input & interaction did not end with Snowmass.**
- Timeline:
  - Planning began in 2011
  - Community Planning Meeting at Fermilab, Oct 11-13, 2012
  - Preparatory meetings held by subgroups during 2012-13
  - Final meeting held at U Minnesota, July 29 - Aug 6, 2013

P5: Science Drivers of Particle Physics

P5 distilled the 11 groups of physics questions from Snowmass into 5 compelling lines of inquiry that show great promise for discovery over the next 10 to 20 years:

- 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

- The Drivers are deliberately **not prioritized** because they are **intertwined**, probably more deeply than currently understood.
- A selected set of different experimental approaches that reinforce each other is required. **Projects are prioritized**.
- The vision for addressing each of the Drivers using a selected set of experiments is given in the report, along with their approximate timescales and how they fit together.

P5 Charge Summary 1

- Develop an updated strategic plan for U.S. high energy physics that can be executed over a 10 year timescale, in the context of a 20-year global vision for the field
- Relevant considerations:
  - More stringent budgets than were considered by previous P5
  - Recent discovery of Higgs boson
  - Observation of large rates of neutrino mixing
  - Fuller understanding of physics to be explored at LHC
  - Global coordination required to realize proposed major new scientific milestones

P5 Charge Summary 2

- Consider appropriate balance of small, mid-scale, and large experiments
- Articulate scientific opportunities which can and cannot be pursued and overall level of support needed in HEP research to achieve scenarios
- Provide detailed perspective on whether and how the pursuit of major international partnerships might fit into the program in each scenario
- Effectively communicate the excitement, impact, and vitality of high-energy physics that can be shared with non-scientific audiences

P5 Process and Meetings 1

- The P5 process had several components, all of which were designed with community engagement in mind:
  - A website was maintained, with information, frequent news, meetings, and a submissions portal with a public archive.
  - There were three large public meetings. All talks were posted online. Emails sent to adjacent communities.
  - There were three physical town halls and three virtual town halls. The virtual town halls were particularly effective for hearing younger voices.
  - A special effort was made to reach out to younger colleagues, with emails to Snowmass Young mailing lists and to PIs urging them to inform their students and post-docs about the process, and a Twitter feed.

P5 Process and Meetings 2

- Experiment/activity input:
  - Each of the major activities considered was given a standard form to fill in, with cost profiles and FTE estimates for each phase of the project (R&D, construction, operations), separated by funding agency, along with information about project level of maturity, contingency, etc.
  - From these, and agency inputs, detailed spreadsheets were developed and used to support the budget exercises.

- Community input via three P5 Workshops:
  - Fermi National Accelerator Laboratory, Nov. 2–4, 2013
    - **Topics**: Snowmass Inputs, International Context, Accelerator-based neutrino program, non-accelerator neutrino program, Town Hall
  - SLAC National Accelerator Laboratory, Dec. 2–4, 2013
    - **Topics**: Dark Matter, Theory, Computing, Science Connections, International Context: Astroparticle Physics Planning in Europe, Cosmic Surveys: Dark Energy and CMB, HE Cosmic Particles and Additional Topics, Town Hall
  - Brookhaven National Laboratory, Dec. 15–18, 2013
    - **Topics**: LHC Upgrades, ILC, Fermilab Proton Accelerator Complex and Opportunities, Proton-driven Rare processes/Precision Experiments, Young Physicists Forum, HE Vision Machines, Town Hall, Accelerator R&D, Instrumentation R&D

P5 Process and Meetings 3

- P5 Panel Meetings:
  - **The panel worked by consensus.**
  - There were full-panel phone calls approximately weekly throughout the process, as well as many subgroups to work on tasks in parallel.
  - The panel had additional face-to-face meetings on the following dates in 2014:
    - 12–14 January, 21–24 February, 5–8 April, and 29–30 April.
  - Panel attendance was remarkably good.
  - All panel discussions had both agency attendance and P5 "alone time". Agency program managers only attended first three large meetings.
  - P5 discussions were held confidential until report rollout.

P5 Process and Meetings 4

- Peer-review:
  - The draft version of report was sent out confidentially to about half a dozen distinguished scientists and experts.
    - Modelled on the questions NAS asks of its reviewers.
  - Yielded helpful feedback: led to a reorganization of the report.
    - First two chapters were self-contained, with Ch. 2 presenting all recommendations. (20 pp)
    - Ch. 3 & 4 presented science drivers and broader impacts. (30 pp)
- HEPAP interactions:
  - There were HEPAP presentations and discussions in September 2013, December 2013, March 2014, and May 2014.
  - Preliminary comments (compared input project needs with budget scenarios, shared prioritization criteria) were presented and discussed at the March meeting, and the Report was presented, discussed, and approved at the May 2014 HEPAP meeting.

Criteria (I): Overall Program Optimization

- Science-driven big picture: where we want to go and how to get there.
- Prioritized portfolio for discovery and exploration.
- International context and optimization:
  - Pursue the most important opportunities wherever they are, and host world-leading facilities that attract the worldwide scientific community.
  - Reliable partnerships are essential.
  - Duplication only when significant value added or when competition helps propel us in important directions. When competing, be clearly leading in key ways.
- Health of the field, sustained productivity:
  - Maintain a stream of results while investing in facilities and future capabilities => a balance of project scales.
  - Maintain and develop critical technical and scientific expertise and infrastructure to enable future discoveries.
  - a guideline: total expenditures on projects around 20-25% of total budget; research fraction >~40% for both project data analysis and blue-sky research to explore unplanned new directions.

Criteria (II): Projects

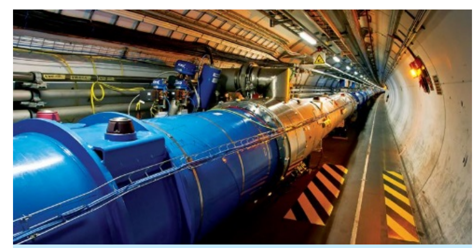
- Science first: how does it address key questions in particle physics?
- Discovery space. How might it change the direction of the field, and what is the value of null results?
- When is it absolutely needed, and how does it fit into the larger picture? What does the experiment add that is unique, is it definitive, and/or where might it lead? Are there alternatives?
- Cost vs value.
  - Is the scope well defined and does it match the physics case? For multidisciplinary/agency projects, does the support match the distribution of science?
  - One main measurement or a preponderance of interesting possible results? Solid result(s) expected or possibly marginal?
  - At what cost/schedule/capability changes does the priority change?
- Take into account previous prioritization and existing commitments. What are the impacts of changes in direction?
- Is the project feasible as proposed? Technical, cost, schedule risks.
- Is U.S.particle physics leadership, or participation, critical, and how?
- What are the other benefits of the project?

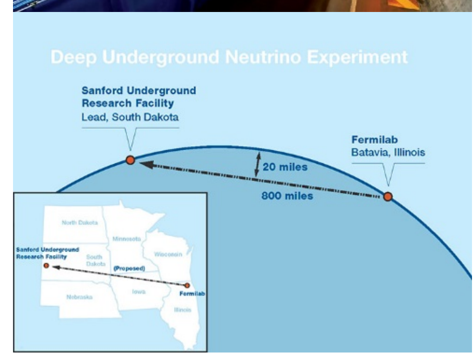
P5: Particle Physics Is a Global Field II

- **“The United States and major players in other regions can together address the full breadth of the field’s most urgent scientific questions if each hosts a unique world-class facility at home and partners in high-priority facilities hosted elsewhere.”**
  - “Strong foundations of international cooperation exist, with the Large Hadron Collider (LHC) at CERN serving as an example of a successful large international science project.”
- **“The field is at a juncture where the major players each plan to host one of the large projects most needed by the worldwide scientific community.”**

P5:Particle Physics is a Global Field III

- **P5 identified two highest-priority large international projects:**
  - Continue strong collaboration in the **Large Hadron Collider** at CERN, including the High-Luminosity LHC accelerator and detector upgrades.
  - Develop a world-leading neutrino program with U.S.-hosted **Long-Baseline Neutrino Facility/Deep Underground Neutrino Experiment** as the centerpiece.
  - A 3rd large project, large-scale involvement in the International Linear Collider in Japan, could not be pursued due to budgetary constraints.





P5 Project Priorities

- Not all projects presented to P5 through the Snowmass process were recommended to move forward
  - Some ongoing programs were ramped down
  - Many proposed projects, all of which were interesting and worthwhile, were not selected.

Summary of Scenarios

	Scenarios			Science Drivers					
Project/Activity	Scenario A	Scenario B	Scenario C	Higgs	Neutrinos	Dark Matter	Cosm. Accel.	The Unknown	Technique (Frontier)
Large Projects									
Muon program: Mu2e, Muon g-2	Y, Mu2e small reprofile needed	Y	Y					✓	I
HL-LHC	Y	Y	Y	✓		✓		✓	E
LBNF + PIP-II	Y, LBNF components delayed relative to Scenario B.	Y	Y, enhanced		✓			✓	I,C
ILC	R&D only	R&D, possibly small hardware contri-butions. See text.	Y	✓		✓		✓	E
NuSTORM	N	N	N		✓				I
RADAR	N	N	N		✓				I
Medium Projects									
LSST	Y	Y	Y		✓		✓		C
DM G2	Y	Y	Y			✓			C
Small Projects Portfolio	Y	Y	Y		✓	✓	✓	✓	All
Accelerator R&D and Test Facilities	Y, reduced	Y, some reductions with redirection to PIP-II development	Y, enhanced	✓	✓	✓		✓	E,I
CMB-S4	Y	Y	Y		✓		✓		C
DM G3	Y, reduced	Y	Y			✓			C
PINGU	Further development of concept encouraged				✓	✓			C
ORKA	N	N	N					✓	I
MAP	N	N	N	✓	✓	✓		✓	E,I
CHIPS	N	N	N		✓				I
LAr1	N	N	N		✓				I
Additional Small Projects (beyond the Small Projects Portfolio above)									
DESI	N	Y	Y		✓		✓		C
Short Baseline Neutrino Portfolio	Y	Y	Y		✓				I

TABLE 1 Summary of Scenarios A, B, and C. Each major project considered by P5 is shown, grouped by project size and listed in time order based on year of peak construction. Project sizes are: Large (>\$200M), Medium (\$50M-\$200M), and Small (<\$50M). The science Drivers primarily addressed by each project are also indicated, along with the Frontier technique area (E=Energy, I=Intensity, C=Cosmic) defined in the 2008 P5 report.

P5 Construction and Physics Timeline

- Panel made difficult decisions
  - Many projects were not recommended
- Final timeline balanced project size and projected science output
  - Ensure scientific return on investment and stable research career path

Significant Changes in Direction - 1

- **Increase investment in construction.**
  - In constrained scenarios, this implies increased fraction of budget toward construction.
- **Reformulate the long-baseline neutrino program as an internationally designed and funded program, with Fermilab as host. Minimum capabilities quantified.**
- **Upgrade the Fermilab proton accelerator complex to produce the world's most powerful neutrino beam**
  - redirecting Project-X activities & some existing accelerator R&D
- **Proceed immediately with a broad second-generation (G2) dark matter direct detection program.**
  - Invest at level significantly above that called for in 2012 joint agency announcement.

Significant Changes in Direction - 2

- **Provide increased particle physics funding of CMB research & projects,**
  - as part of the core particle physics program, in context of multiagency, interdisciplinary partnerships.
- **Re-align activities in accelerator R&D, which is critical to enabling future discoveries, based on new physics information and long-term needs.**
  - Reassess the Muon Accelerator Program (MAP), and consult with international partners on the early termination of MICE.
  - In the general accelerator R&D program, focus on outcomes and capabilities that will dramatically improve cost effectiveness for mid- and far-term accelerators.

Community Response

- 2,331 US particle physics community members signed a letter of support to DOE and NSF (organized by DPF).

Continuing Communications

- We produce and regularly update community materials on usparticlephysics.org
  - Coordinated effort of APS DPF Executive Committee, Fermilab Users' Executive Committee, SLAC Users Organization, and U.S. LHC Users Association
  - **Material includes a one-sheet on "Progress and Priorities" regarding implementation of the P5 strategy**
    - Top priorities, recent results, program advances, looking forward

Personal Observations

- A short report is much more difficult to write than a long report, but it is worth the effort.
  - Worked with a scientific editor on the final version.
- It is OK to change direction if there is a clear, objective reason. Tough choices are rewarded.
- It is OK to show some passion. See Report Preface and the following slide.
- Inputs from prior prioritization activities (e.g., Astro2010/NWNH) were carefully considered. See slide 16 on Criteria.
- P5 panel was charged with representing the interests of the field, not "representative" of their subfield or institution. Worked by consensus. Everyone pulled together to find solutions.
- Outward-facing panel: large number of members from other countries, by design, thoughtful leaders of strategic planning and those familiar with U.S. program.
- The buzz (what people say is in the report) is apparently at least as important as what is actually in the report!
  - Continued messaging matters.

P5 Panel Perspective (from Preface)

- This is a challenging time for particle physics. The science is deeply exciting and its endeavors have been extremely successful, yet funding in the U.S. is declining in real terms. The report offers important opportunities for U.S. investment in science, prioritized under the tightly constrained budget scenarios in the Charge.
- We had the responsibility to make the tough choices for a world-class program under each of these scenarios, which we have done. At the same time, we felt the responsibility to aspire to an even bolder future.
- Wondrous projects that address profound questions inspire and invigorate far beyond their specific fields, and they lay the foundations for next-century technologies we can only begin to imagine. Particle physics is an excellent candidate for such investments.
- With foundations set by decades of hard work and support, U.S. particle physics is poised to move forward into a new era of discovery.

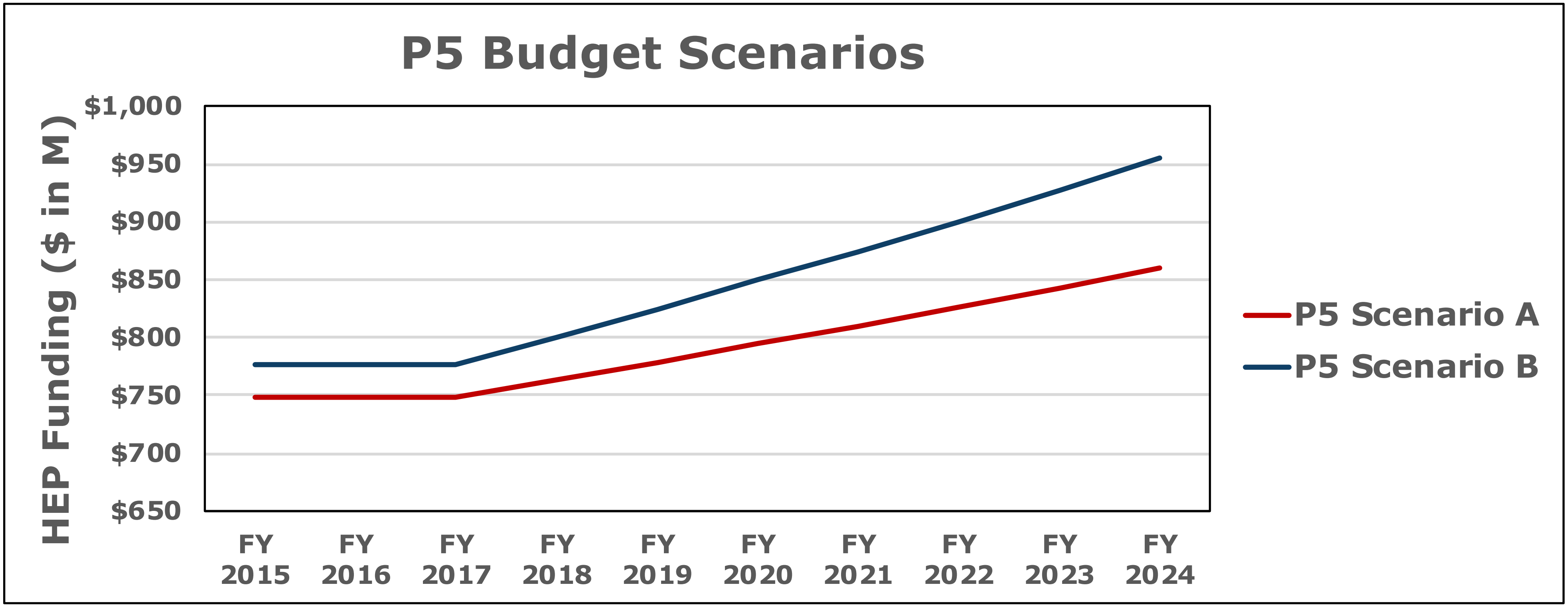
- More generally, we strongly affirm the essential importance of fundamental research in all areas of science.

- Our field is ready to move forward.

Discussion

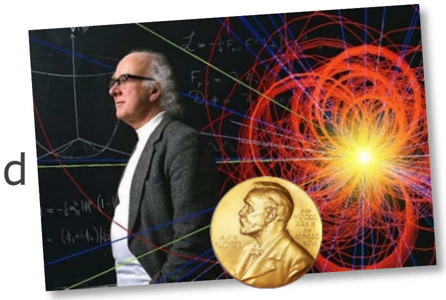
P5 Budget Scenarios

- P5 considered 10-year HEP budget scenarios within a 20-year vision for the global field
  - Scenario A was the lowest constrained budget scenario
  - Scenario B was a slightly higher constrained budget
  - Scenario C was unconstrained, but prioritized list of specific activities



P5: High Energy Physics Overview

- **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 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

- **Our community has made difficult choices.**
  - The updated strategy in the May 2014 Particle Physics Project Prioritization Panel (P5) report 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

P5: Particle Physics Is a Global Field

From Chapter 1 of the P5 Report

- **"The scientific program required to address all of the most compelling questions of the field is beyond the finances and the technical expertise of any one nation or region."**

- **"The capability to address these questions in a comprehensive manner is within reach of a cooperative global program."**

Context – Changes since previous P5

- Scientific:
  - Higgs discovered; relatively low Higgs mass
  - An important neutrino mixing parameter measured; relatively large value
  - Three Nobel Prizes: CKM, Higgs, Dark Energy; demonstrates importance of diversity of topic and scale
- Programmatic:
  - DUSEL didn’t succeed, SURF cont’d; JDEM didn’t succeed
  - Tevatron & B-factory operations ended
  - Budgets lower than anticipated
  - International cooperation continues to be successful

An important change in direction: LBNE → LBNF

P5 recognized that the Long Baseline Neutrino Experiment, which was supported in the 2008 P5 report and had reached CD-1, would not meet the science goals identified by the community and informed by recent neutrino oscillation measurements.

From the P5 report:

- **The minimum requirements to proceed are the identified capability to reach an exposure of at least 120 kt*MW*yr by the 2035 timeframe, the far detector situated underground with cavern space for expansion to at least 40 kt LAr fiducial volume, and 1.2 MW beam power upgradable to multi-megawatt power. The experiment should have the demonstrated capability to search for supernova (SN) bursts and for proton decay, providing a significant improvement in discovery sensitivity over current searches for the proton lifetime.**
- These minimum requirements are not met by the current LBNE project's CD-1 minimum scope.
- A more ambitious long-baseline neutrino facility has also been urged by the Snowmass community study and in expressions of interest from physicists in other regions. To address even the minimum requirements specified above, the expertise and resources of the international neutrino community are needed. **A change in approach is therefore required.**
- **Recommendation 13: Form a new international collaboration to design and execute a highly capable Long-Baseline Neutrino Facility (LBNF) hosted by the U.S. To proceed, a project plan and identified resources must exist to meet the minimum requirements in the text. LBNF is the highest-priority large project in its timeframe.**

P5: Benefits and Broader Impacts

From the P5 report:

Particle physics shares with other basic sciences the need to innovate, invent, and develop technologies to carry out its mission to explore the nature of matter, energy, space and time.

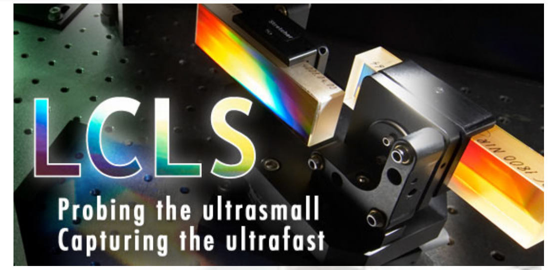
Advanced particle accelerators, cutting-edge particle detectors, and sophisticated computing techniques are the hallmarks of particle physics research.

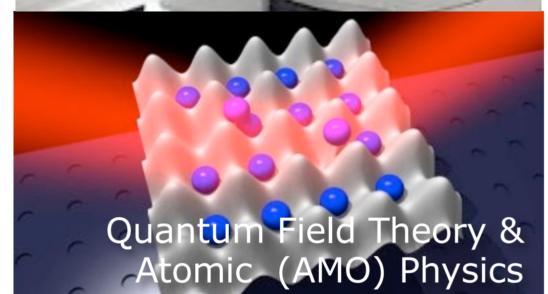
This dedicated research has benefited tremendously from progress in other areas of science to advance the current state of technology for particle physics.

In return, developments within the particle physics community have enabled basic scientific research and applications in numerous other areas.

Research in particle physics inspires young people to engage with science.

This broad, connected scientific enterprise provides tremendous benefits to society as a whole.





Building for Discovery

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

Report of the Particle Physics Project Prioritization Panel

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.

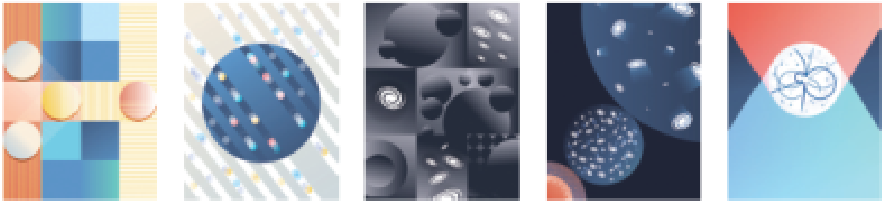
Particle physics is a highly successful, discovery-driven science. It explores the fundamental constituents of matter and energy, and it reveals the profound connections underlying everything we see, including the smallest and the largest structures in the Universe. Earlier investments have been rewarded with recent fundamental discoveries, and upcoming opportunities will push into new territory. Research in 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, and a portfolio of small projects that includes short-baseline neutrino experiments.
- 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.
- 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

Report of the Particle Physics Project Prioritization Panel

U.S. DEPARTMENT OF ENERGY | Office of Science

Rolling out the Report

- P5 Report was presented publicly & approved by HEPAP in May 2014.
- All ready at the time of the May HEPAP meeting:
  - International partner consultations
  - Draft versions of 1-page overview and talking points
  - Press release and web features ready to go
- Followed quickly by:
  - Community: Virtual Town Hall, emails, news items, briefings by phone and talks/discussions at universities and labs, and conferences
  - Briefing decision makers as requested
- Continued talks/discussions at community meetings, universities, and labs, international committees

Snowmass / P5 Interface

- These topics were suggested to the community as guidance for Snowmass reports and white papers:
  - What are the most compelling science questions in HEP that can be addressed in the next 10 to 20 years and why
  - What are the primary experimental approaches that can be used to address them? Are they likely to answer the question(s) in a "definitive" manner or will follow-on experiments be needed?
  - What are the "hard questions" (science, technical, cost…) that a given experiment or facility needs to answer to respond to perceived limitations in its proposal?
- P5 built on the investment in the Snowmass process and outcomes.
  - P5 used the Snowmass reports and white papers as its starting point for prioritization.
  - Community input & interaction did not stop with Snowmass.