# Particle Physics Project Prioritization Panel (P5) Strategic Planning

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# Acknowlegements & Thank you's

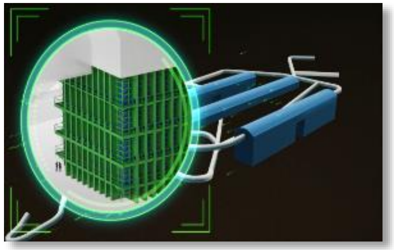
- Michael Cooke (DOE HEP)
  - Provided invaluable support to P5 throughout the process
  - Prepared the slides upon which this presentation is based
- Steven Ritz (UCSC, P5 Chair)
  - Provided skillful and intrepid leadership
  - Provided the content of many of today's slides
  - Continued leadership of community follow-up
- The P5 Panel
  - Wisdom and devotion
- DOE HEP and NSF PHY
  - Guidance and trust

# Introduction

# 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


- P5 report enables discovery science with a balanced program that deeply intertwines U.S. efforts with international partners
  - **U.S. particle physics community** strongly supports strategy
  - **U.S. Administration** has supported implementing the P5 strategy through each President's Budget Request
  - **U.S. Congress** has supported implementing the P5 strategy through the language and funding levels in appropriations bills
  - **International community** recognizes strategy through global partnerships



# 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

# Preparing for P5

# 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/
- 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

# 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.

# P5 Charge

# P5 Charge Summary 1

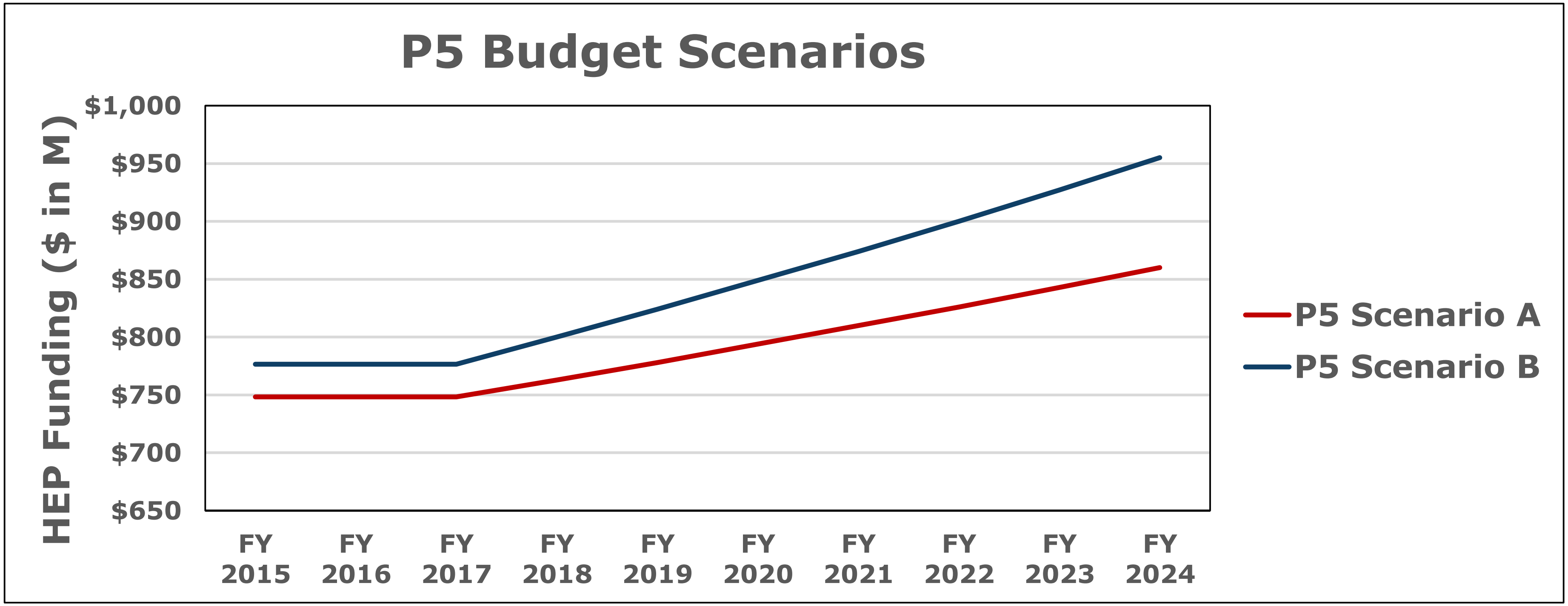
- Develop an updated strategic plan for U.S. high energy physics that can be executed over a 10 year timescale, in the context of a 20-year global vision for the field
- Relevant considerations:
  - More stringent budgets than were considered by previous P5
  - Recent discovery of Higgs boson
  - Observation 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 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



# Forming P5

# Constituting the P5 panel

- Careful choice of chair
  - Criteria: experienced, strong committee leader; familiar w/ P5 process; not perceived to be conflicted wrt critical decisions to be made
- Careful choice of panel
  - Called for nominations so as not to overlook any excellent candidates
    - Good community response: ~800 nominations for ~400 individuals
  - Consulted widely, including with agencies
  - Scientifically respected, broad view of field, perceived as fair and unbiased
  - Composition intended to cover range of expertise and roughly reflect demographics of field
    - Broadly representative wrt to subfield, geography and gender
  - Strong international representation (2 each Europe and Japan)
    - Focus on leaders of strategic planning and on leaders familiar with U.S. program
- P5 panel was charged with representing the interests of the field, not of their subfield or institution.

# 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*

# P5 Process & Meetings

# 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.
  - 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 would-be final version of report was sent out confidentially to about half a dozen distinguished scientists.
  - Yielded quite useful feedback regarding clarity and compelling-ness of the report
  - Led to a complete reorganization of 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 were presented and discussed at the March meeting, and the Report was presented, discussed, and approved at the May 2014 HEPAP meeting.

# 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

# 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.

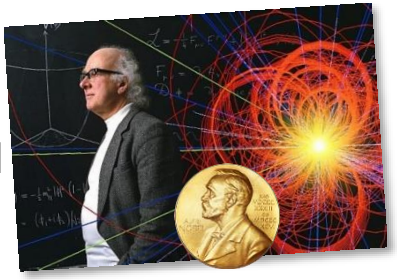
# Criteria (II): Projects

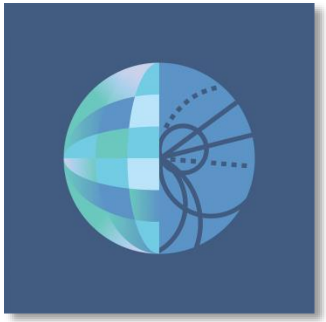
- Science first: how does it address key questions in particle physics?
- Discovery space. How might it change the direction of the field, and what is the value of null results?
- When is it absolutely needed, and how does it fit into the larger picture? What does the experiment add that is unique, is 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?

# Contents of the P5 Report

# 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





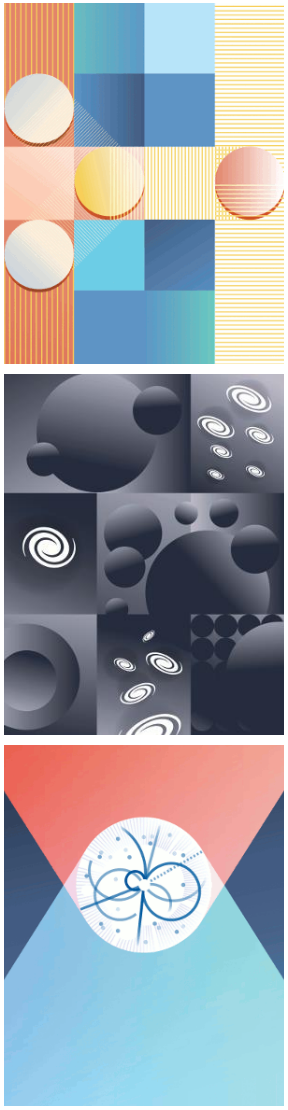
- **Particle physics is global.**
  - To address the most pressing scientific questions and maintain its status as a global leader, the U.S. must both host a unique, world-class facility and be a partner on the highest priority facilities hosted elsewhere
- **Our community has made difficult choices.**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

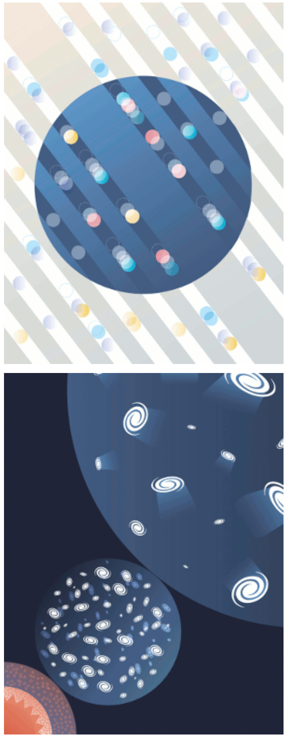
# P5: Science Drivers of Particle Physics

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. **2013*
- Pursue the physics associated with **neutrino mass.** **2015*
- Identify the new physics of **dark matter.**
- Understand **cosmic acceleration**: dark energy and inflation. **2011*
- **Explore the unknown**: new particles, interactions, and physical principles

** Since 2011, three of the five science drivers have been lines of inquiry recognized with Nobel Prizes*





# 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."**

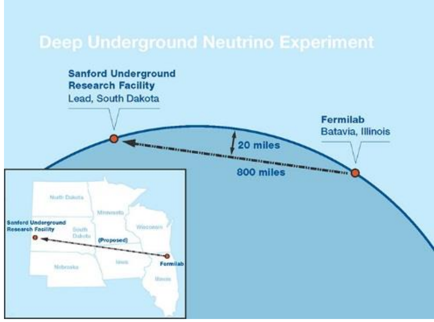

- **"The capability to address these questions in a comprehensive manner is within reach of a cooperative global program."**

# 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.

# An important change in direction: LBNE $\rightarrow$ 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 Project Priorities

- Not all projects presented to P5 through the Snowmass process were selected to move forward
  - Some ongoing programs were ramped down (MAP)
  - Many proposed projects were turned down

## Summary of Scenarios

| Project/Activity | Scenarios: Scenario A | Scenarios: Scenario B | Scenarios: Scenario C | Science Drivers: Higgs | Science Drivers: Neutrinos | Science Drivers: Dark Matter | Science Drivers: Cosm. Accel. | Science Drivers: 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.**
- **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 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.

# 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.

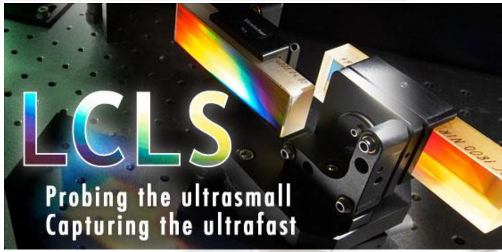
Advanced particle accelerators, cutting-edge particle detectors, and sophisticated computing techniques are the hallmarks of particle physics research.

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

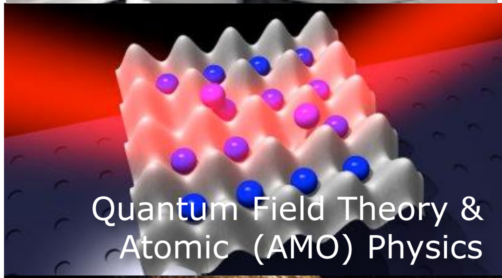
In return, developments within the particle physics community have enabled basic scientific research and applications in numerous other areas.

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

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








# Rolling Out the P5 Report

# The End Game: 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

# 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

# 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.

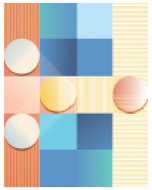
**Particle physics is a highly successful, discovery-driven science.** It explores the fundamental constituents of matter and energy, and it reveals the profound connections underlying everything we see, including the smallest and the largest structures in the Universe. Earlier investments have been 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.

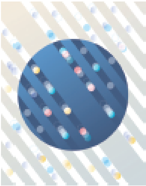
**Choices were required.** The updated strategy recommends investments in the best opportunities, chosen from a large number of excellent options, in order to have the biggest impact and make the most efficient use of resources over the coming decade.

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

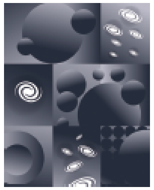
- Use the Higgs boson as a new tool for discovery
- Pursue the physics associated with neutrino mass
- Identify the new physics of dark matter
- Understand cosmic acceleration: dark energy and inflation
- Explore the unknown: new particles, interactions, and physical principles



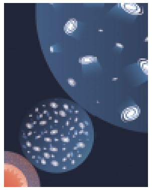
Higgs boson



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

NSF

# Rolling out the report

- **Roll out in Washington: Good reception**
  - From Secretary of Energy to DOE Office of HEP
  - Executive Office of the President
    - Office of Management & Budget (OMB) & Office of Science & Technology Policy (OSTP)
    - FY16 budget in preparation
  - Congress (relevant committees of both House and Senate)
  - Common Washington questions: International collaboration, MAP
- **Roll out in community: Good reception**
  - HEPAP, Virtual Town Hall, conferences & workshops
  - APS Physics Policy Committee
  - Laboratory Directors
  - Influential physics leaders
  - Common community questions:
    - Internationalization of neutrino program, Muon Accelerator Program (MAP), impact on research groups, prospects for future machines in US.
  - International community

# Community & Public Response to P5

- U.S. particle physics community enthusiastically supports the new plan.
  - 2,331 community members signed a letter of support to DOE and NSF (organized by DPF)
- Major news outlets reported on the recommendations.
  - Most science publications pointed out that the top priority outlined in the P5 report is the continued participation in the LHC experiments and its upgrades
  - Often focused on the proposed construction of a billion-dollar-plus Long-Baseline Neutrino Facility, a project that hadn't received much media attention in the past
  - An Associated Press article on the report and the proposed LBNF was carried in more than 270 media outlets worldwide

# Continuing Communications

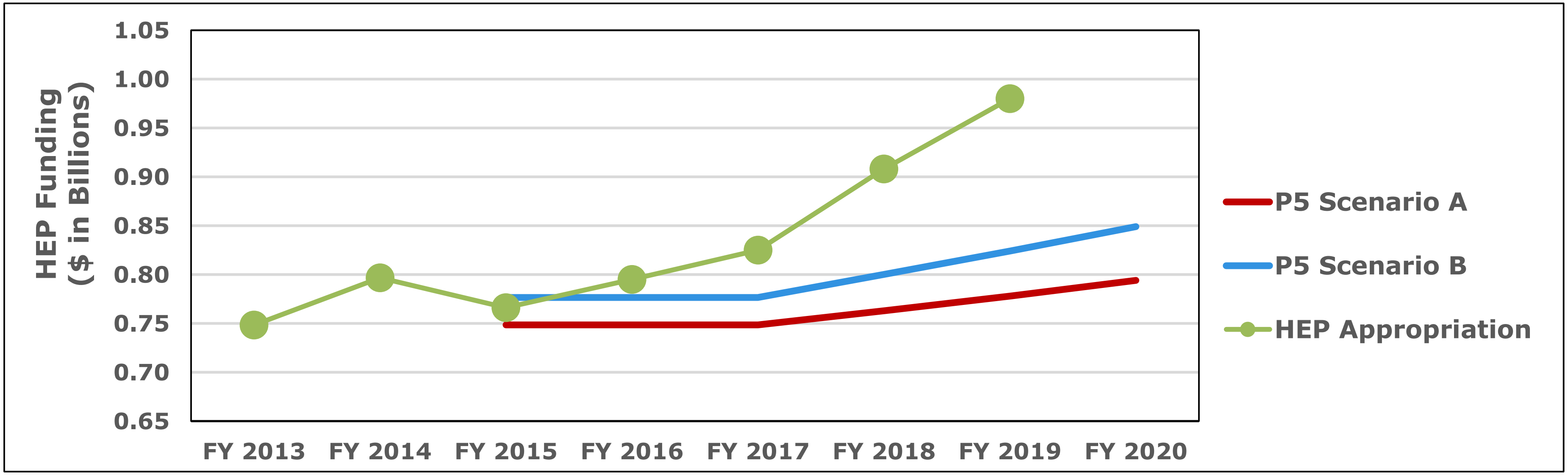
- Community groups and Steve Ritz (P5 chair) produce and regularly update community materials on usparticlephysics.org
  - Coordinated effort of DPF Executive Committee, Fermilab Users' Executive Committee, SLAC Users Organization, and U.S. LHC Users Association
  - Material includes a one-sheet on "Progress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

# Important Impacts of the P5 Report

# U.S. Congress Supports P5 Strategy

- FY 2019 Senate Energy and Water Development Appropriations Report:
  - "The Committee recommends $1,010,000,000 for High Energy Physics. **The Committee strongly supports the Department's efforts to advance the recommendations of the Particle Physics Project Prioritization Panel Report [P5]**, which established clear priorities for the domestic particle physics program…"

**"Four years into executing the P5, the Committee commends the Office of Science and the high energy physics community for achieving significant accomplishments and meeting the milestones and goals set forth in the strategic plan…"**



# Growing International Partnerships

- CERN is an important partner with DOE through cooperative agreements signed in 2015 and 2017
- UK-U.S. Science and Technology Agreement signed Sep. 20, 2017
  - Major project under this agreement is UK investment in LBNF/DUNE/PIP-II program
- DOE and DAE-India Project Annex II on Neutrino Research signed April 16, 2018
  - Expands accelerator science collaboration with India to include the science for neutrinos
- DOE and Italian Ministry of Education, Universities and Research agreements on neutrinos and accelerators
  - Agreement under an umbrella agreement on neutrino science collaboration signed June 28, 2018
  - Annex agreement for PIP-II accelerator signed Dec. 4, 2018
- Statements of Interest each from CEA and CNRS (France), expressing interest in U.S.-hosted Neutrino Program, signed December 2018
- Close coordination by DOE with U.S. Government agencies, including the State Department, on establishing cooperative agreements
  - Actively pursuing engagements with other potential global partners to advance particle physics program



**CERN**


**UK**


**India**



**Italy**

# Why is 2014 P5 Report Successful?

# Generally Important to Success

- **The report addresses different audiences.**
  - HEP community, DOE HEP & SC, OMB, Congress
- **The report presented a strategic plan, a well-balanced, scientifically compelling program, not strictly a prioritization of projects.**
- **What are some generally important points?**
  - Community support
  - Credible panel
  - Strongly prioritized the science case as the deciding factor
  - Restructuring of LBNF/DUNE into a scientifically strong project
  - Presentation of report and articulation of rationales strengthened by peer-review.
  - Report provided rationale of prioritization
  - Communicating the report (P5 Chair S. Ritz was important here)

# Additionally key to HEP Community

- **What else was important to the HEP community?**
  - Snowmass process built community buy-in.
    - Understood as important from the NP experience
    - Particularly the large final meeting
  - P5 built on the investment in Snowmass process and outcomes
    - But was not constrained by them
  - Open to input, transparent process, communication channels throughout process
    - Public meetings, town halls, further input, communications.
  - Restructuring of LBNF/DUNE into a scientifically strong project

# Additionally key to Administration & Congress

- **What else was important to DOE HEP and SC?**
  - Credible panel that devoted itself to the task, and held itself to a high standard; panel represented the field not special interests
  - Realistic, implementable plan (hard work on realistic budgets, made difficult choices)
  - Addressed perceptions and concerns of officials
  - Support of HEPAP, DPF, and Community
- **What else is important to Congress?**
  - Consistent, coherent message
  - Progress on ongoing medium-scale projects as large-scale projects started
  - International aspect
  - Sustained community support
  - Ongoing communication of the P5 strategic plan

U.S. DEPARTMENT OF ENERGY

Office of Science

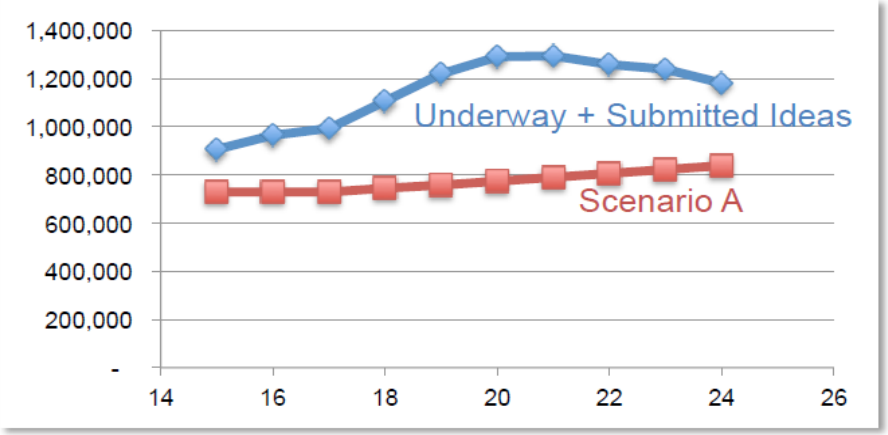
# Timeline for Updating the U.S. Strategy

- **The May 2014 P5 report was successful because it was well informed by the science community**, including information from:
  - 2010 New Worlds, New Horizons in Astronomy and Astrophysics
  - 2012 Report of the Subcommittee on Future Projects of High Energy Physics (Japan)
  - 2013 European Strategy for Particle Physics Report
  - 2013 U.S. Particle Physics Community-driven “Snowmass” process
- The timeline of processes that impact strategic planning is:
  - 2018-20: New NAS Astronomy and Astrophysics Decadal Survey
  - 2019: Japan position on ILC
  - 2019: Start of European Strategy for Particle Physics process
  - 2020: Release of updated European Strategy for Particle Physics
  - 2020: Earliest opportunity for National Science Board to approve obligating MREFC for HL-LHC
- From a DOE perspective, the earliest that new “Snowmass,” NAS Elementary Particle Physics Decadal Survey, and P5 processes could begin is 2020
  - Relative timing of Snowmass, P5, and NAS EPP Decadal survey to be determined
  - Enables receiving new P5 recommendations in time to inform the FY 2024/25 budget
- **U.S. community encouraged to work with international collaborators in developing other regional plans with a global vision for particle physics**

# Key Elements of Strategic Planning

- Assess the opportunities to address the big scientific drivers and how they fit together.
- Budgetary constraints compared with ideas presented to P5:

DOE-funded component, for illustration:

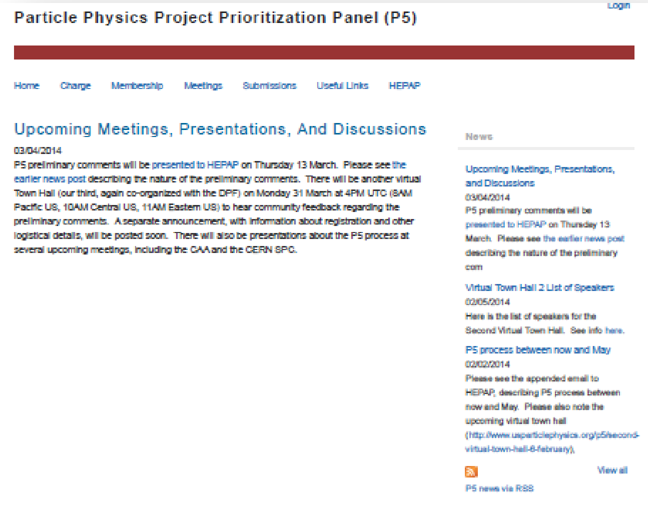



- Integrated Difference ~$4B
- Ideas already cost-constrained (and many are pre-CD-0)!
- scenario B ~$0.5B above A
- **Scenario A is especially difficult:** near a tipping point beyond which historic balance is not possible.

- National planning in the global context.
- Balancing investments
  - Projects, Facilities, R&D, Research (including Theory)
  - Host large, world-leading facilities
  - Small projects bookkept and prioritized as groups
  - Goal-oriented and blue-sky R&D
  - Check timeframes for project results, avoid long gaps
- Criteria

# Summary of P5 Process

- All info available on P5 website, frequently updated with News (RSS and Twitter feeds)
- Meetings:
  - Face-to-face
    - Three big, open, topical meetings: 2-4 Nov, 2-4 Dec, 15-18 Dec
    - Plus 12-14 Jan, 21-24 Feb, 5-8 April, 29-30 April
  - Frequent phone calls since September. Continuous work between meetings.
- Large Project/Activity worksheets for all phases (R&D, construction, operations) to help ensure uniformity, data quality.
- Continuous effort to maximize community interactions, including:
  - Numerous emails, outreach to younger physicists
  - Town halls at all 3 big meetings
  - Virtual town halls (with DPF) 8 Jan, 6 Feb, 31 Mar
  - Public submissions portal
  - Many ongoing discussions and consultations
- Peer review of report draft 5-10 May




*http://interactions.org/p5*

- Internal deliberations worked by consensus.
- No topic or option was off the table. Every alternative we could imagine was considered.

Community engagement has been essential.

# The Science Drivers

- 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.
- **The Science Drivers**:
  - **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.

- **Recommendation 2: Pursue a program to address the 5 science Drivers.**

# P5 Panel Perspective

- 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.