The P5 Vision at Year-1

R. Tschirhart

2015 LQCD All Hands Meeting

Fermilab

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

Report of the Particle Physics Project Prioritization Panel (P5)

HEPAP
22 May 2014

S. Ritz

Significant Developments Since the 2008 P5 Report

- Physics!
  - Higgs boson discovered at a relatively low mass, pointing the way to the next steps and informing choices for long-term planning.
  - Three Nobel Prizes related to particle physics: Quark Mixing and Symmetries, Dark Energy, Higgs Boson.
  - A key neutrino mixing parameter, $\sin^2(2\theta_{13})$, was measured to be relatively large, enabling the next steps in a campaign to understand the implications of the tiny, but non-zero, neutrino masses.
- These successes demonstrate the deep value of diversity of topic and project scale.
- New technology and innovative approaches are creating fresh opportunities that promise an even brighter future.

- Programmatic changes
  - the Deep Underground Science and Engineering Laboratory (DUSEL) did not proceed, although the Sanford Underground Research Facility (SURF) laboratory continues to develop. The Joint Dark Energy Mission (JDEM) did not proceed.
  - Tevatron collider operations and PEP-II/B-factory operations ended.
  - Inflation-adjusted funding continued to decline

- Snowmass! ➔

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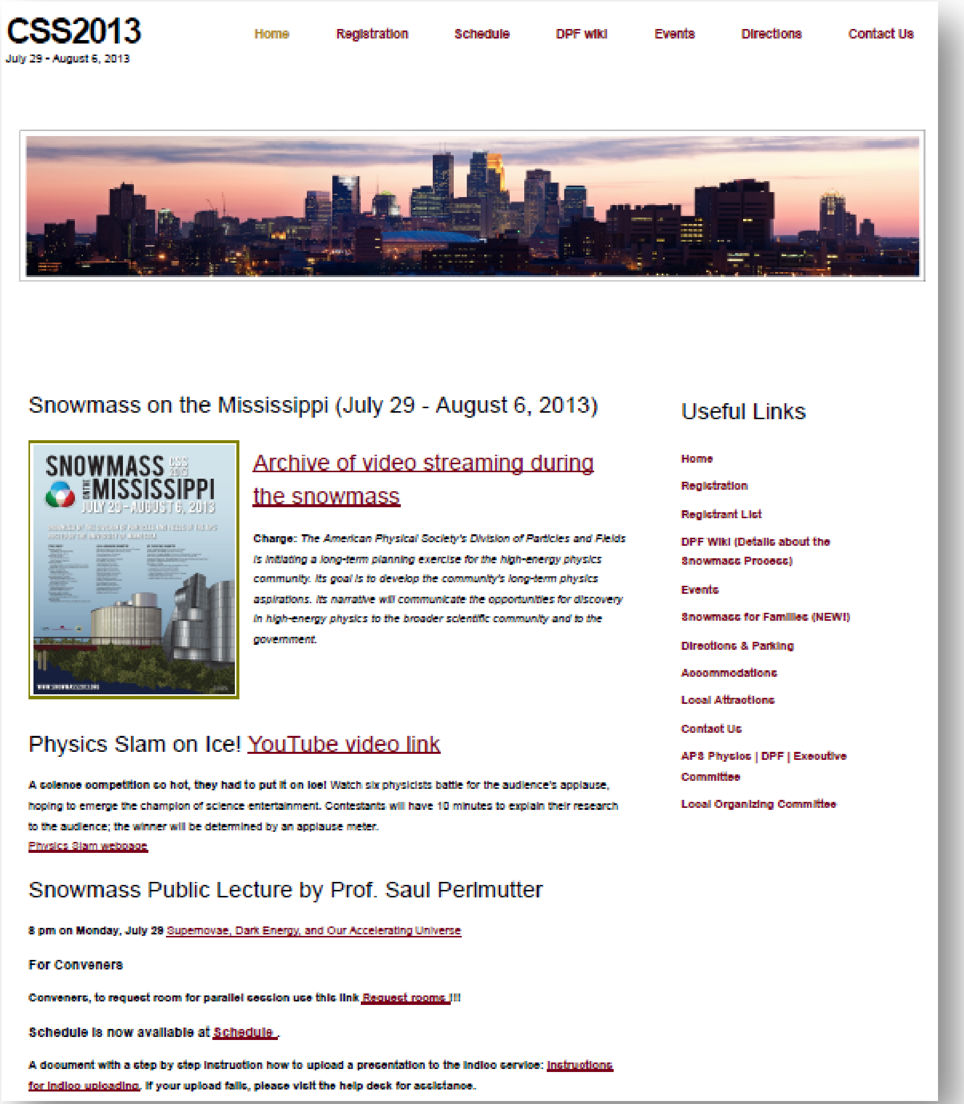
Snowmass

Snowmass, the yearlong community-wide study preceding P5, was invaluable.

A vast number of scientific opportunities were investigated, discussed, and summarized in the Snowmass reports.



See http://www.hep.umn.edu/css2013/ and http://www.slac.stanford.edu/econf/C1307292/

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Science Drivers

- We distilled the eleven groups of physics questions from Snowmass* into five 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 is 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 – their approximate timescales and how they fit together – is given in the report.

* See Appendix D and http://www.slac.stanford.edu/econf/C1307292/

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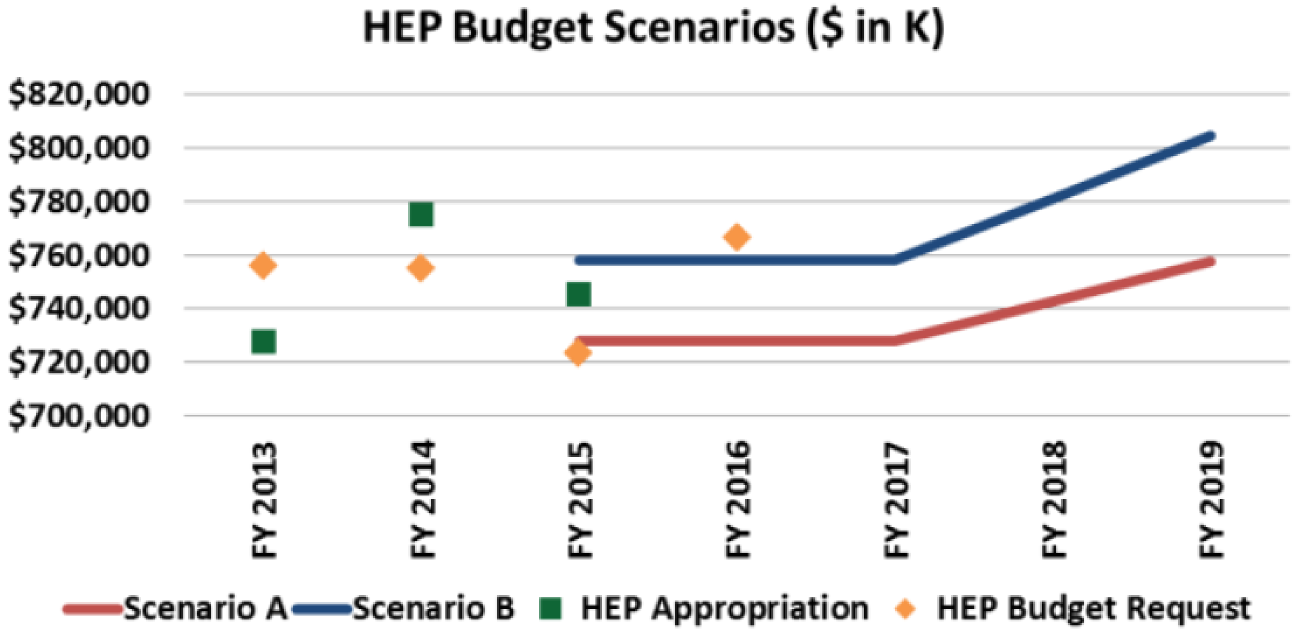
Context: P5 HEP Budget Scenarios

- P5 was charged to consider three 10-year budget scenarios for HEP within the context of 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
  - Scenario C was "unconstrained," but not considered unlimited



**Budget Request and Appropriations do not include SBIR/STTR*

Jim Siegrist, HEPAP meeting April 2015

Scenario A Considerations

- Scenario A is precarious. It approaches the point beyond which hosting a large ($1B scale) project in the U.S. would not be possible while maintaining the other elements necessary for mission success, particularly a minimal research program, the strong leadership position in a small number of core, near-term projects, which produce a steady stream of important new physics results, and advances in accelerator technology.
- Without the capability to host a large project, the U.S. would lose its position as a global leader in this field, and the international relationships that have been so productive would be fundamentally altered.

Use the Higgs boson as a new tool for discovery

- The recently discovered Higgs boson is a form of matter never before observed.
  - What principles determine its effects on other particles? How does it interact with neutrinos or with dark matter? Is there one Higgs particle or many? Is the new particle really fundamental, or is it composed of others?
  - The Higgs boson offers a unique portal into the laws of Nature, and it connects several areas of particle physics. Any small deviation in its expected properties would be a major breakthrough.

- The full discovery potential of the Higgs will be unleashed by percent-level precision studies of the Higgs properties. The measurement of these properties is a top priority in the physics program of high-energy colliders.
  - The Large Hadron Collider (**LHC**) will be the first laboratory to use the Higgs boson as a tool for discovery, initially with substantial higher energy running at 14 TeV, and then with ten times more data at the High-Luminosity LHC (**HL-LHC**). The HL-LHC has a compelling and comprehensive program that includes essential measurements of the Higgs properties.
  - An e^+e^- collider can provide the next outstanding opportunity to investigate the properties of the Higgs in detail. The International Linear Collider (**ILC**) is the most mature in its design and readiness for construction. The ILC would greatly increase the sensitivity to the Higgs boson interactions with the Standard Model particles, with particles in the dark sector, and with other new physics. The ILC will reach the percent or sub-percent level in sensitivity.
  - Longer-term future-generation accelerators bring prospects for even better precision measurements of Higgs properties and discovery potential.

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Pursue the physics associated with neutrino mass

- Propelled by surprising discoveries from a series of pioneering experiments, neutrino physics has progressed dramatically over the past two decades, with a promising future of continued discovery.
- Many aspects of neutrino physics are puzzling. Powerful new facilities are needed to move forward, addressing:
  - What is the origin of neutrino mass? How are the masses ordered (referred to as mass hierarchy)? What are the masses? Do neutrinos and anti-neutrinos oscillate differently? Are there additional neutrino types or interactions? Are neutrinos their own antiparticles?
- The U.S. is well positioned to host a world-leading neutrino physics program, which includes an optimized set of short- and long-baseline neutrino oscillation experiments
  - The long-term focus is a reformulated venture referred to here as the Long Baseline Neutrino Facility (**LBNF**), an internationally designed, coordinated, and funded program with Fermilab as host.
  - LBNF would combine a high-intensity neutrino beam and a large-volume precision detector sited underground a long distance away to make accurate measurements of the oscillated neutrino properties. This large detector would also search for proton decay and neutrinos from supernova bursts.
- A powerful, wideband neutrino beam would be realized with Fermilab's **PIP-II** upgrade project, which provides very high intensities in the Fermilab accelerator complex.
- Cosmic surveys and a variety of other small experiments will also make important progress in answering these questions.

Identify the new physics of dark matter

- Astrophysical observations imply that the known particles make up only about one-sixth of the total matter in the Universe. The rest is dark matter (DM). The properties of dark matter particles, which are all around us, are largely unknown.
- Experiments are poised to reveal the identity of dark matter, a discovery that would transform the field of particle physics, advancing the understanding of the basic building blocks of the Universe. There are many well-motivated ideas for what dark matter could be, including
  - weakly interacting massive particles (WIMPs), axions, and new kinds of neutrinos.

- Direct detection experiments are sensitive to dark matter interactions with ordinary particles in the laboratory and will follow a progression from currently proposed second-generation (**DM G2**) experiments to much larger third-generation (**DM G3**) experiments.
- Indirect detection experiments, such as the **CTA** gamma-ray observatory, can spot the particle debris from interactions of relic dark matter particles in space. Cosmic surveys are sensitive to dark matter properties through their effects on the structures of galaxies.
- Experiments now at the LHC and eventually at future colliders seek to make dark matter particles in the laboratory for detailed studies.

Understand cosmic acceleration: dark energy and inflation

- With the telescopes that peer back in time and high-energy accelerators that study elementary particles, scientists have pieced together a story of the origin and evolution of the Universe. An important part of this story is the existence of two periods during which the expansion of the Universe accelerated.
  - A primordial epoch of acceleration, called inflation, occurred during the first fraction of a second of existence. The cause is unknown -- fundamentally new physics at ultra-high energies. A second distinct epoch of accelerated expansion began more recently and continues today, presumed to be driven by some kind of dark energy, which could be related to Einstein's cosmological constant, or driven by a different type of dark energy that evolves with time.

- Understanding inflation is possible by measuring the characteristics of two sets of primordial ripples: those that grew into the galaxies observed today, and gravitational waves, undulations in space and time that may have been observed just months ago by the BICEP2 telescope looking at the cosmic microwave background (CMB). Current CMB probes will lead to a **Stage 4 Cosmic Microwave Background (CMB-S4)** experiment, with the potential for important insights into the ultra-high energy physics that drove inflation.

- Understanding the second epoch requires better measurements:
  - The Dark Energy Spectroscopic Instrument (**DESI**) can determine the properties of dark energy to the percent level over the course of billions of years. The Large Synoptic Survey Telescope (**LSST**), measuring the positions, shapes, and distances of billions of galaxies, will perform many separate tests of the properties of dark energy.
  - Together, they can also probe the possibility that, instead of dark energy, new laws beyond those introduced by Einstein are responsible for the recent cosmic acceleration.

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Explore the unknown: new particles, interactions, and physical principles

- There are clear signs of new phenomena awaiting discovery beyond those of the other four Drivers. Particle physics is a discovery science defined by the search for new particles and new interactions, and by tests of physical principles.

- Producing new particles at colliders:
  - Well-motivated extensions of the Standard Model predict that a number of such particles should be within reach of LHC. HL-LHC will extend the reach for new particles that could be missed by LHC. In the event that one or more new particles are already discovered during LHC running, HL-LHC experiments will be essential to reveal the identities and underlying physics of these particles.

- Detecting the quantum influence of new particles:
  - The existence of new particles that are too heavy to be produced directly at high-energy colliders can be inferred by looking for quantum influences in lower energy phenomena, using different kinds of particles as probes that are sensitive to different types of new particles and interactions. Some notable examples are a revolutionary increase in sensitivity for the transition of a muon to an electron in the presence of a nucleus **Mu2e** (Fermilab) and **COMET** (J-PARC), further studies of rare processes involving heavy quarks or tau leptons at **Belle II** (KEK) and **LHCb** (LHC), and a search for proton decay using the large neutrino detectors of the **LBNF** and proposed **Hyper-K** experiments.

- Future Opportunities:
  - In the longer term, **very high-energy e^+e^- colliders** and **very high-energy proton colliders** could extend the search for new particles and interactions, as well as enable precision studies of the Higgs boson and top quark properties . Upgrades at Fermilab (**PIP-II** and additional improvements) will offer further opportunities to detect the influence of new particles in rare processes.

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Table 1
Summary of Scenarios

Project/Activity	Scenarios: Scenario A	Scenario B	Senario C	Science Drivers: 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 contributions. 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.

Figure 1
Construction and Physics Timeline

FIGURE 1 Approximate construction (blue; above line) and expected physics (green; below line) profiles for the recommended major projects, grouped by size (Large [>$200M] in the upper section, Medium and Small [<$200M] in the lower section), shown for Scenario B. The LHC: Phase 1 upgrade is a Medium project, but shown next to the HL-LHC for context. The figure does not show the suite of small experiments that will be built and produce new results regularly.

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Project-specific Recommendations

#1-2:

Recommendation 1: Pursue the most important opportunities wherever they are, and host unique, world-class facilities that engage the global scientific community.

Recommendation 2: Pursue a program to address the five science Drivers.

Project-specific Recommendations

#3-9:

3: Develop a mechanism to reassess the project priority at critical decision stages if costs and/or capabilities change substantively.

4: Maintain a program of projects of all scales, from the largest international projects to mid- and small-scale projects.

5: Increase the budget fraction invested in construction of projects to the 20%–25% range.

6: In addition to reaping timely science from projects, the research program should provide the flexibility to support new ideas and developments.

7: Any further reduction in level of effort for research should be planned with care, including assessment of potential damage in addition to alignment with the P5 vision.

8: As with the research program and construction projects, facility and laboratory operations budgets should be evaluated to ensure alignment with the P5 vision.

9: Funding for participation of U.S. particle physicists in experiments hosted by other agencies and other countries is appropriate and important but should be evaluated in the context of the Drivers and the P5 Criteria and should not compromise the success of prioritized and approved particle physics experiments.

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Project-specific Recommendations

#10-11:

Recommendation 10: Complete the LHC phase-1 upgrades and continue the strong collaboration in the LHC with the phase-2 (HL-LHC) upgrades of the accelerator and both general-purpose experiments (ATLAS and CMS). The LHC upgrades constitute our highest-priority near-term large project.

Recommendation 11: Motivated by the strong scientific importance of the ILC and the recent initiative in Japan to host it, the U.S. should engage in modest and appropriate levels of ILC accelerator and detector design in areas where the U.S. can contribute critical expertise. Consider higher levels of collaboration if ILC proceeds.

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Project-specific Recommendations

#12-15:

Recommendation 12: In collaboration with international partners, develop a coherent short- and long-baseline neutrino program hosted at Fermilab.

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.

Recommendation 14: Upgrade the Fermilab proton accelerator complex to produce higher intensity beams. R&D for the Proton Improvement Plan II (PIP-II) should proceed immediately, followed by construction, to provide proton beams of >1 MW by the time of first operation of the new long-baseline neutrino facility.

Recommendation 15: Select and perform in the short term a set of small-scale short-baseline experiments that can conclusively address experimental hints of physics beyond the three-neutrino paradigm. Some of these experiments should use liquid argon to advance the technology and build the international community for LBNF at Fermilab.

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Project-specific Recommendations

#16/17/18/21:

Recommendation 16: Build DESI as a major step forward in dark energy science, if funding permits (see Scenarios discussion below).

Recommendation 17: Complete LSST as planned.

Recommendation 18: Support CMB experiments as part of the core particle physics program. The multidisciplinary nature of the science warrants continued multiagency support.

Recommendation 21: Invest in CTA as part of the small projects portfolio if the critical NSF Astronomy funding can be obtained.

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Courtesy Dana Claire Simpson .com

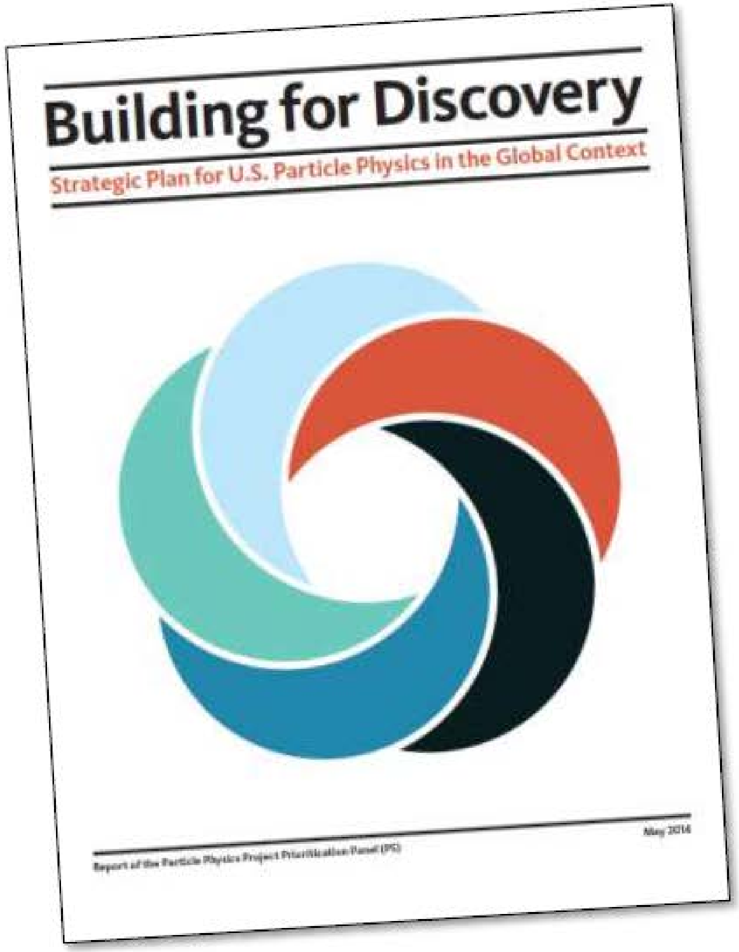
Status of the DOE High Energy Physics Program

HEPAP Meeting, April 6, 2014

Jim Siegrist
Associate Director
for High Energy Physics
Office of Science, U.S. Department of Energy

Enabling the Next Discovery

Science drivers identify the scientific motivation while the **Research Frontiers** provide a useful categorization of experimental techniques



	Energy Frontier	Intensity Frontier	Cosmic Frontier
Higgs Boson	●		
Neutrino Mass		●	●
Dark Matter	●	●	●
Cosmic Acceleration			●
Explore the Unknown	●	●	●

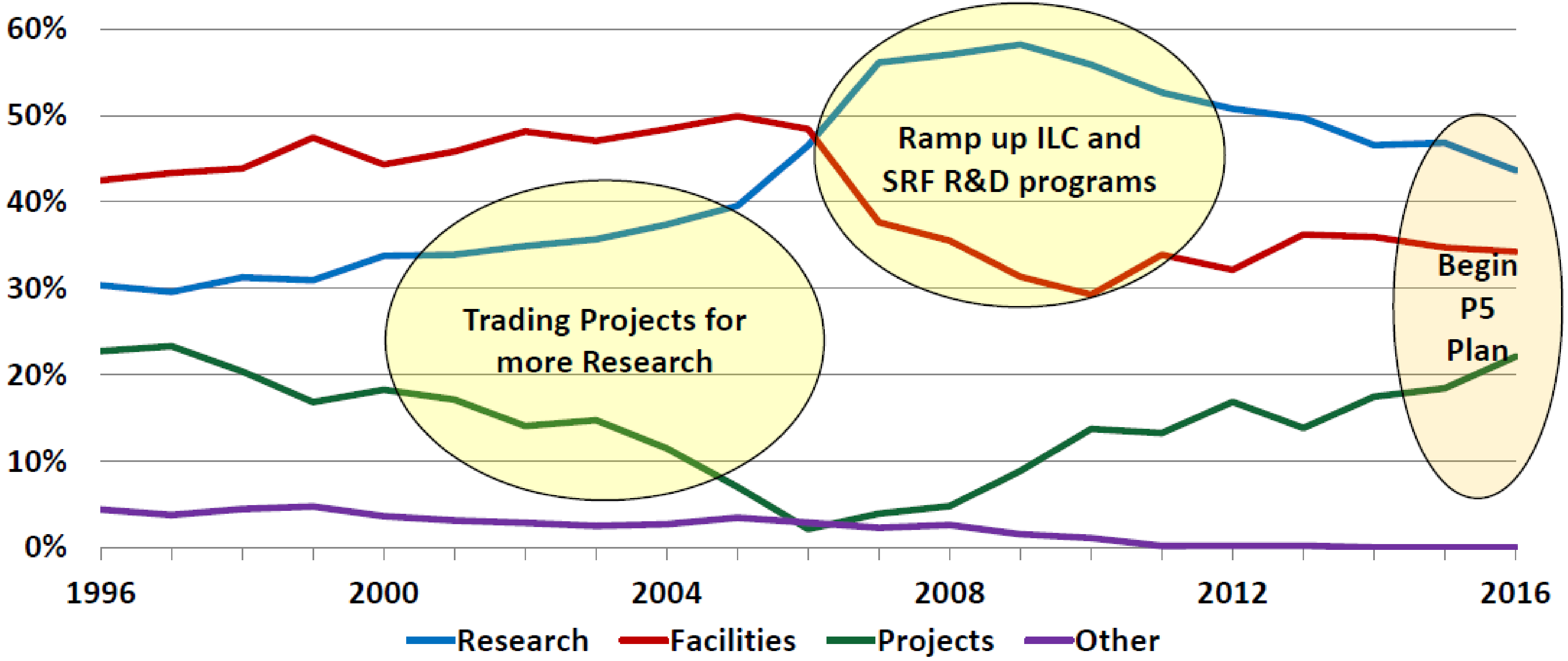
Jim Siegrist, HEPAP meeting April 2015

The FY 2016 HEP Budget Request

- **HEP is implementing the strategy detailed in the May 2014 report of the Particle Physics Project Prioritization Panel (P5), formulated in the context of a global vision for the field**
  - HEP Addresses the five compelling science drivers with research in three frontiers and related efforts in theory, computing and advanced technology R&D
  - Increasing emphasis on international partnerships (such as LHC) to achieve critical physics goals
- **Energy Frontier: Continue LHC program with higher collision energy (13+ TeV)**
  - The U.S. will continue to play a leadership role in LHC discoveries by remaining actively engaged in LHC data analysis and the initial upgrades to the ATLAS and CMS detectors
- **Intensity Frontier: Develop a world-class U.S.-hosted Long Baseline Neutrino Facility**
  - Continue the design process for an internationalized LBNF and development of a short baseline neutrino program that will support the science and R&D required to ensure LBNF success
  - Fermilab will continue to send world's highest intensity neutrino beam to NOvA, 500 miles away to Ash River, MN
- **Cosmic Frontier: Advance our understanding of dark matter and dark energy**
  - Immediate development of new capabilities continue in dark matter detection with baselining of 2nd-generation experiments; and in dark energy exploration with baselining of DESI and fabrication of LSST camera.

Funding Trends by Fiscal Year

(FY 2016 shows President's Request)



- P5 report recommendation suggests increasing the project budget fraction to 20%–25%
  - "Addressing the [science] Drivers in the coming and subsequent decades requires renewed investment in projects."
- P5 report strategy has informed the HEP request in the FY 2016 DOE budget

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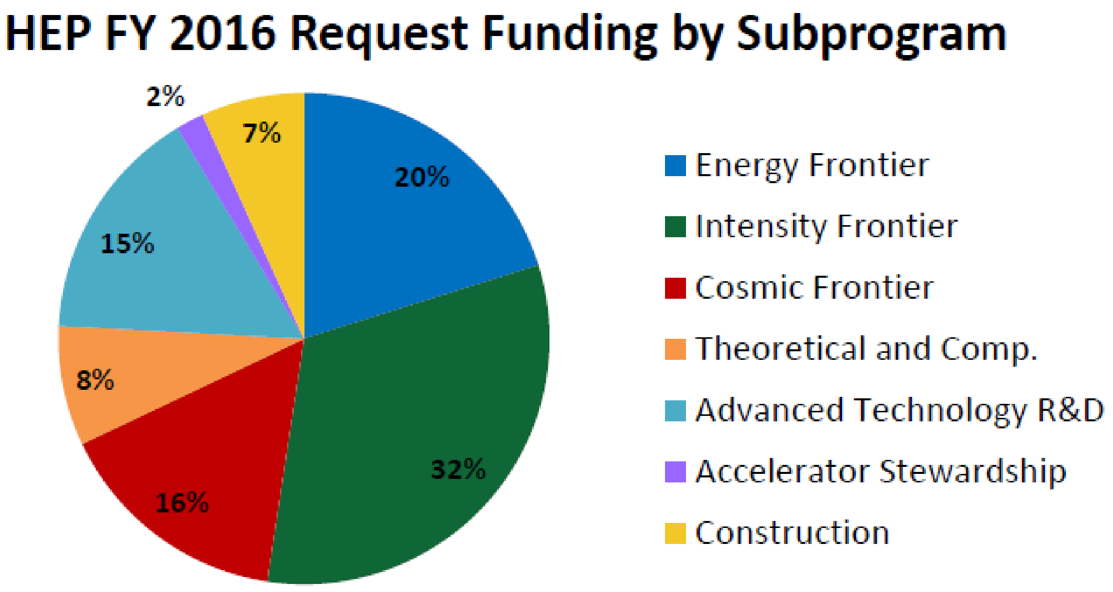
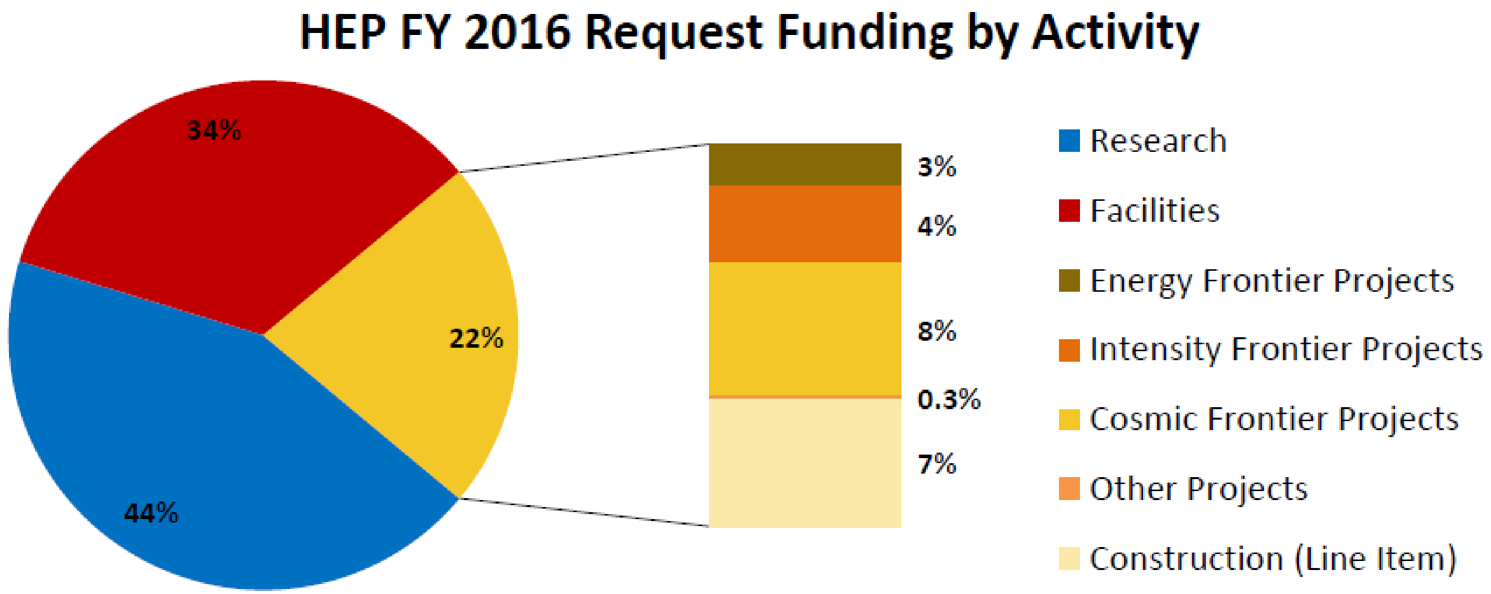
FY 2016 HEP Budget Request Overview





Context: P5 HEP Budget Scenarios

- P5 was charged to consider three 10-year budget scenarios for HEP within the context of a 20-year vision for the global field
  - Scenario A was the lowest constrained budget scenario
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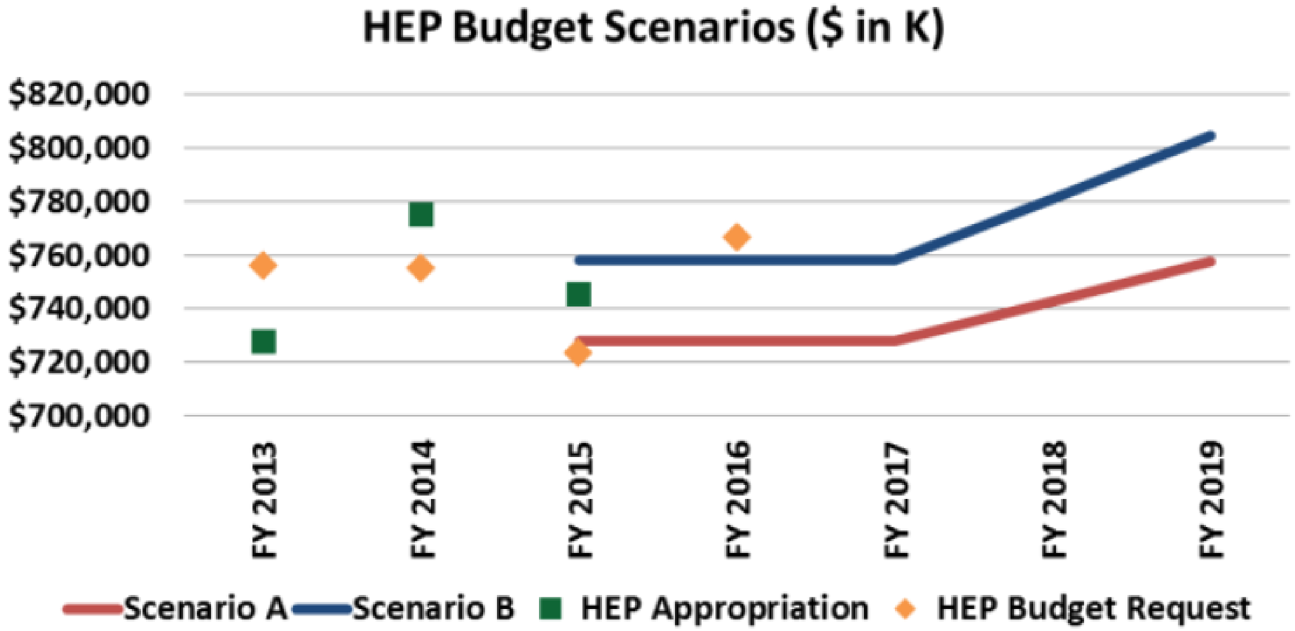
  - Scenario C was “unconstrained,” but not considered unlimited



*Budget Request and Appropriations do not include SBIR/STTR

Jim Siegrist, HEPAP meeting April 2015

FY 2016 HEP Funding by Activity

HEP Funding Category ($ in K)	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	Explanation of Changes (FY16 vs. FY15)
Research	373,932	337,383	334,703	*Research reductions support project investments*
Facilities	278,683	265,125	262,658	*Maintain efficient operations of facilities and ongoing experiments*
Projects	71,305	105,698	113,401	
Energy Frontier Projects	*0*	*15,000*	*19,000*	*Ramp up in LHC detector upgrades fabrication*
Intensity Frontier Projects	*37,400*	*43,970*	*33,700*	*Continue g-2 and FNAL acc. upgrade profiles; some LBNE efforts move to construction*
Cosmic Frontier Projects	*30,705*	*45,728*	*58,701*	*Increase supports LSSTcam, DESI and second generation dark matter experiments*
Other Projects	*3,200*	*1,000*	*2,000*	*Planned Lattice QCD hardware acquisition*
Construction (Line Item)	51,000	37,000	56,100	*Planned profile for Mu2e; engineering and design for LBNE*
SBIR/STTR	21,601*	20,794	21,138	
Total	**796,521***	**766,000**	**788,000**	

** SBIR/STTR added to FY 2014 for comparison to FY 2015/2016*

FY 2016 High Energy Physics Budget

HEP Funding Category ($ in K)	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	Explanation of Changes (FY16 vs. FY15)
Energy Frontier	152,386	147,584	154,555	*LHC detector upgrade fabrication; R&D for high-luminosity LHC upgrades*
Intensity Frontier	250,987	264,224	247,196	*Operations and upgrade of NuMI for NOvA and MicroBooNE; R&D for LBNF and SBN*
Cosmic Frontier	96,927	106,870	119,325	*Planned ramp-up of LSSTcam; support of DESI and 2nd generation dark matter experiments*
Theoretical and Comp.	64,275	59,274	60,317	*Planned increase in Lattice QCD project; slight reduction in theory research efforts*
Advanced Technology R&D	150,270	120,254	115,369	*Reductions reflect shift to P5 priority areas; MAP reduction continues in response to P5*
Accelerator Stewardship	9,075	10,000	14,000	*Increase supports new research topic areas and expands open test facility efforts*
Construction (Line Item)	51,000	37,000	56,100	*Planned profile for Mu2e; engineering and design for LBNF*
SBIR/STTR	21,601*	20,794	21,138	
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IMPLEMENTING THE P5 STRATEGY

Implementing a World-Class Neutrino Program

- **World-class short- and long-baseline neutrino program rapidly coming together, with strong support the international community**
  - Tomorrow's agenda includes highlights of the Workshop on the Intermediate Neutrino Program and discussion of the related Funding Opportunity Announcement
- **LBNF and DUNE are moving forward quickly and have presented plans that could present the opportunity to pursue scientific results from an underground detector in the early 2020s**
  - Next steps will include a "refresh" review of DUNE to assess the rapid progress that has been made in bringing together the international community
  - Outcome of this review and status of our international agreements with interested partners will inform any updates to the cost estimate and spending profile…

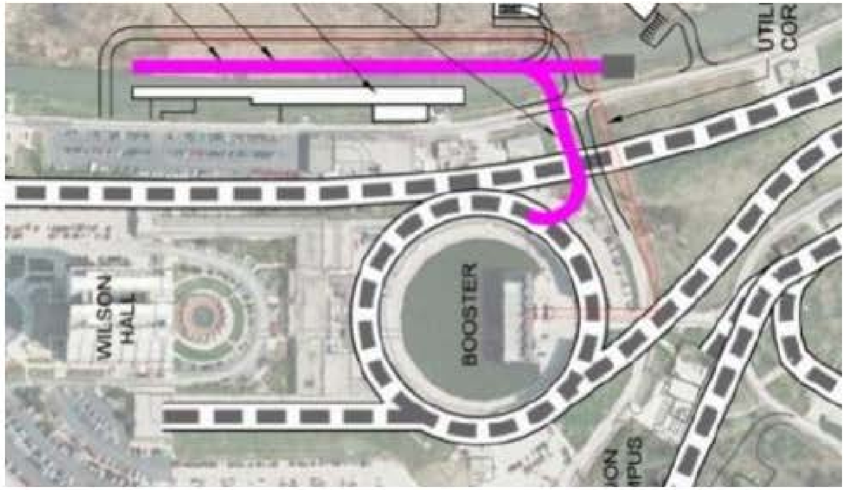
Accelerated Deployment of LBNF/DUNE

- **LBNF is prominent in being the first large infrastructure hosted by the U.S. for the international particle physics community**
  - This international effort is recognized as being important to the U.S. government
- **Accelerating the deployment of LBNF/DUNE would allow achieving science results early and enhance our ability to accommodate contributions from international partners**
  - Plans are being discussed that would accelerate the deployment of DUNE with of the first of four 10 kiloton underground detectors installed in the 2021 time frame
  - Realizing this schedule will be challenging!
- **We are investigating accelerating the LBNF/DUNE schedule in a way that aligns with the P5 vision to establish this international facility**

Jim Siegrist, HEPAP meeting April 2015

Proton Improvement Plan II (PIP-II)

- P5 recommendation:
  - “Upgrade the Fermilab proton accelerator complex to produce higher intensity beams. R&D for the Proton Improvement Plan II (PIP-II) should proceed immediately, followed by construction, to provide proton beams of >1 MW by the time of first operation of the new long-baseline neutrino facility.”
- PIP-II supports longer term physics research goals by providing increased beam power to LBNF while providing a platform for the future
- Infrastructure and workforce development due to LCLS-II work at Fermilab will be leveraged in support of PIP-II, further advancing SRF capabilities



HWR

SSR1

SSR2

LB650

HB650

P5 Guidance on Energy Frontier Machines

- P5 report identified LHC upgrades as the highest priority near-term large project and specifically recommends:
  - Complete "Phase-1" (2018) upgrades of ATLAS and CMS experiments
  - Continue collaborations for the accelerator upgrades for the High-Luminosity LHC and "Phase-2" upgrades of ATLAS and CMS (2023-25)
    - U.S. collaborates with CERN and global partners in superconducting magnet R&D, with particular emphasis on Nb_3Sn technology
- P5 noted the strong scientific importance of the ILC global project
  - Recommended modest and appropriate levels of ILC accelerator and detector design in areas where the U.S. can contribute critical expertise
- P5 recognized that a very high-energy proton-proton collider is the most powerful future tool for direct discovery of new particles and interactions under any scenario
  - Participate in global conceptual design studies and critical path R&D for future very high-energy proton-proton colliders
  - Continue to play a leadership role in superconducting magnet technology focused on the dual goals of increasing performance and decreasing costs
    - Eventual technical involvement in other R&D subjects will be informed by the HEPAP Accelerator R&D Subpanel Report

DOE Goals for Future Circular Collider Work

- A critical first step is for active U.S. theorists to do their part to guide agreement in the U.S. (and global?) community on the energy and luminosity requirements of a very high energy proton-proton collider, while fleshing out physics goals and driving discussion in the U.S.
  - The HEP community may want to establish a Snowmass-like process in this focused area to help engage the community in these studies
  - A limited, focused effort is required, since we must maintain balance with the current DOE program dedicated to implementing the exciting but challenging program that has been laid out for us by P5
- DOE looks forward to receiving a white paper from the U.S. high-field magnet community for coordinated U.S. participation in an international R&D activity on SC magnets for a very high energy proton-proton collider
  - Establishing a coordinated plan within the U.S. and with international partners is crucial for implementing a successful program
  - Builds on the successful collaboration on the LHC and HL-LHC magnets
  - Level of effort will be informed by the Accelerator R&D Subpanel Report

DOE Goals for ILC Work

- Japan has expressed interest in hosting the International Linear Collider (ILC) and is actively working through a decision making process
- As recommended in the P5 strategic plan, DOE plans to provide modest and appropriate support through the period of Japanese decision making
  - U.S. has played key roles in the design of the ILC accelerator, including leadership in the Global Design Effort
  - Continued intellectual contributions to the accelerator and detector design are still necessary to enable a site-specific bid proposal
  - P5 recommended ILC support at some level in all budget Scenarios through a decision point within the next 5 years
  - Report emphasized that support for these efforts would ensure a strong position for the U.S. within the ILC global project
- DOE is making an effort to maintain ILC accelerator activities in balance with other programmatic priorities

Progress on Internationalization of Long-baseline Program

- Significant progress has been made on internationalization of LBNE:
  - International Meeting for Large Neutrino Infrastructures, Paris, June 22-23, 2014
  - FNAL Interagency Meeting on a Global Neutrino Program, July 14, 2014
  - World Neutrino Summit at Fermilab, July 21–22, 2014
  - Interim International Executive Board (iIEB) Board Meeting at Fermilab, September 23-24, 2014
  - iIEB SURF site visit, October 8-9
  - Fermilab has developed a first draft of a governance document
  - Open community meetings for potential PIs held at CERN and Fermilab on December 5 and 12, respectively
  - International governance white paper drafted in December
  - Letter of Intent delivered to Fermilab PAC on December 21
- First meeting of the Experiment at the Long Baseline Neutrino Facility (ELBNF) collaboration took place January 22-23, 2015
  - 145 institutions from 23 countries

HEP Program: FY 2016 Priorities

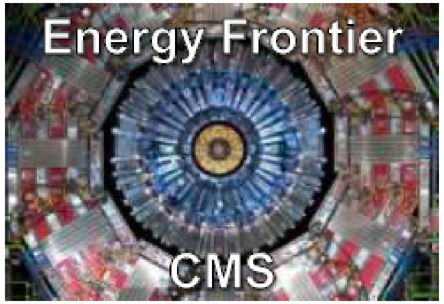
Jim Siegrist, HEPAP meeting April 2015

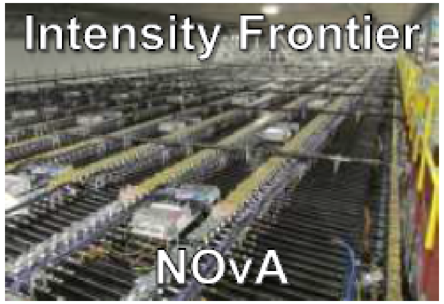
- **HEP is implementing the strategy detailed in the May 2014 report of the Particle Physics Project Prioritization Panel (P5), formulated in the context of a global vision for the field**
  - HEP Addresses the five compelling science drivers with research in three frontiers and related efforts in theory, computing and advanced technology R&D
  - Increasing emphasis on international partnerships (such as LHC) to achieve critical physics goals

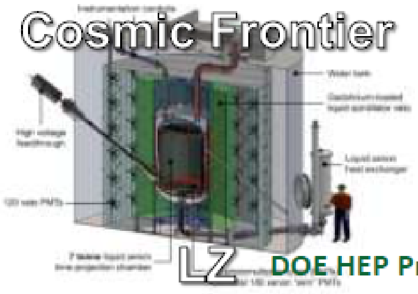
- **Energy Frontier: Continue LHC program with higher collision energy (13+ TeV)**
  - The U.S. will continue to play a leadership role in LHC discoveries by remaining actively engaged in LHC data analysis and the initial upgrades to the ATLAS and CMS detectors

- **Intensity Frontier: Develop a world-class U.S.-hosted Long Baseline Neutrino Facility**
  - Continue the design process for an internationalized LBNF and development of a short baseline neutrino program that will support the science and R&D required to ensure LBNF success
  - Fermilab will continue to send world's highest intensity neutrino beam to NOvA, 500 miles away

- **Cosmic Frontier: Advance our understanding of dark matter and dark energy**
  - Immediate development of new capabilities continue in dark matter detection with baselining of 2nd-generation experiments; and in dark energy exploration with baselining of DESI and fabrication of LSST camera.







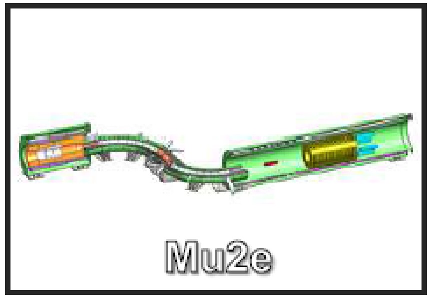
	Energy Frontier	Intensity Frontier	Cosmic Frontier
Higgs Boson	●		
Neutrino Mass		●	●
Dark Matter	●	●	●
Cosmic Acceleration			●
Explore the Unknown	●	●	●

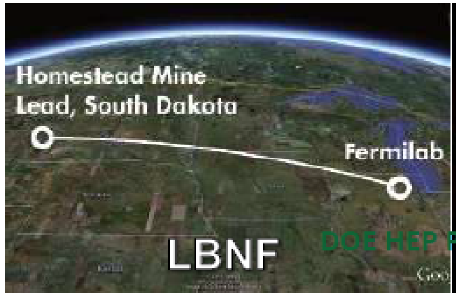
HEP Program: FY 2016 Priorities

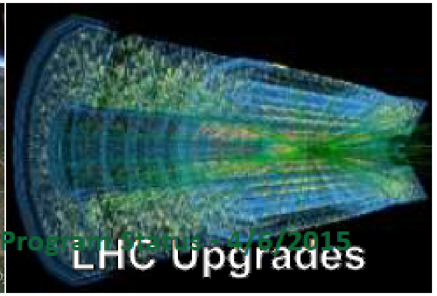
- **Accelerator Stewardship**
  - This subprogram focuses on the broader applications of accelerator technologies, including major thrusts in technology to enable ion-beam cancer therapy and R&D for high-power ultrafast lasers
  - The FY 2016 funding request provides support for a new research thrust in energy and environmental applications of accelerators and expands the open test facilities effort
  - The main facility supporting this subprogram, the Brookhaven Accelerator Test Facility (ATF), will undergo relocation and expansion in FY 2016 to accommodate more users

- **Construction/Major Items of Equipment (MIEs) support reflects P5 priorities:**
  - The Long Baseline Neutrino Facility (LBNF) continues its design phase as the project baseline cost and technical scope are revised while incorporating international in-kind contributions
  - The LHC ATLAS and CMS Detector Upgrade projects continue fabrication
  - Muon g-2 continues accelerator modifications and fabrication of the beamline and detectors
  - LSSTcam fabrication support increases according to planned profile
  - Dark Energy Spectroscopic Instrument (DESI) will be baselined in 2016
  - Fabrication proceeds on the dark matter experiment MIEs: SuperCDMS-SNOLab and LZ
  - Construction continues for the Muon to Electron Conversion Experiment (Mu2e)

Jim Siegrist, HEPAP meeting April 2015

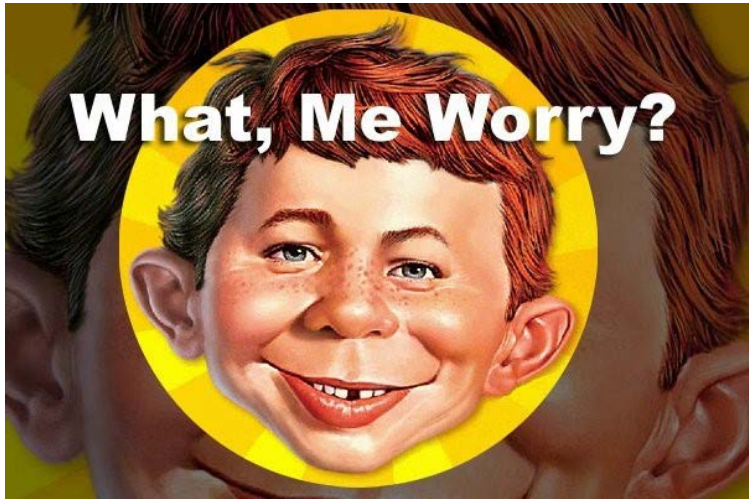






P5 and the LQCD community

- Quark flavor physics experiments are “off-shored”
- Funding for HEP research programs under stress from Projects
- Greater emphasis on “directed” R&D
- What if BSM is not found in LHC Run-2?



- Precision Higgs Physics, FCC.

- Competitive muon research program:
  g-2, Mu2e, proton charge radius, etc.

- Leading neutrino research program:
  sub-percent control of asymmetry systematics, etc.

Bibliography

- HEPAP website: http://science.energy.gov/hep/hepap
- HEPAP meetings: http://science.energy.gov/hep/hepap/meetings/
- P5 report: http://science.energy.gov/hep/hepap/reports/