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Science

# Status of the DOE High Energy Physics (HEP) Program

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*AAAC meeting*

*February 27, 2018*

*Kathy Turner - Program Manager, Cosmic Frontier*

*Office of High Energy Physics*

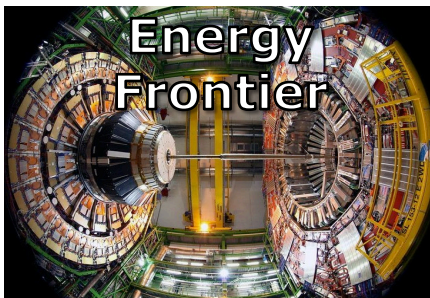
*Office of Science, U.S. Department of Energy*

# HEP: FY19 Budget Highlights

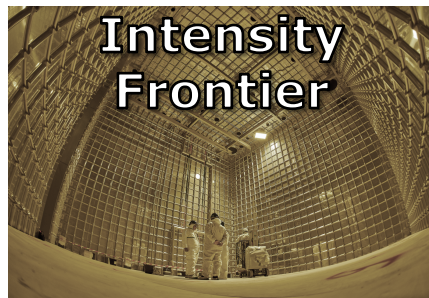
→ Understanding how the universe works at its most fundamental level

## FY 2019 Request is guided by priorities of Administration, SC, and P5 report

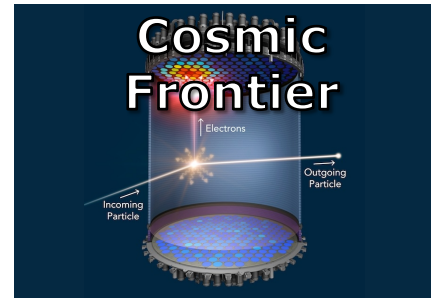
- ▶ “Building for Discovery” by supporting highest priority P5 strategic plan (2014) projects to enable the future program
- ▶ Research support advances P5 science drivers and world-leading, long-term R&D in Advanced Technology, Accelerator Stewardship, and Quantum Information Science (QIS)
- ▶ Operations support enables world-class research at HEP User Facilities & Experiments
- ▶ **Energy Frontier: Actively engage in successful LHC program and HL-LHC upgrades**
  - ▶ The High-Luminosity Large Hadron Collider (HL-LHC) ATLAS & CMS detector upgrades (new MIE starts) and the HL-LHC Accelerator Upgrade Project are together considered one of P5’s highest priority large projects
  - ▶ The U.S. will continue to play a leadership role in LHC discoveries by remaining actively engaged in analysis of world’s highest energy particle collider data
- ▶ **Intensity Frontier: Support establishing a U.S.-hosted world-leading neutrino program**
  - ▶ LBNF/DUNE is P5’s highest priority U.S.-hosted large project and FY 2019 investments in far-site civil construction are crucial to enable scheduled delivery of contributions from international partners
  - ▶ Support Short-Baseline Neutrino (SBN) program at Fermilab, DUNE prototype R&D efforts at CERN, and continued funding for PIP-II project to upgrade the Fermilab Accelerator Complex
- ▶ **Cosmic Frontier: Advance our understanding of dark matter and dark energy**
  - ▶ P5 recommended complementary suite of projects to search for dark matter candidates and study dark energy; request supports full planned funds for **LZ, SuperCDMS-SNOLAB, and DESI**; **LSST-camera** funding completed in FY18



CMS at the LHC



protoDUNE



LZ

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

# FY 2019 President's Budget Request

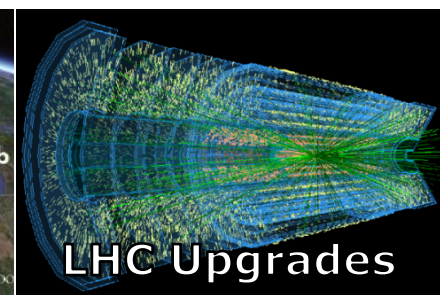
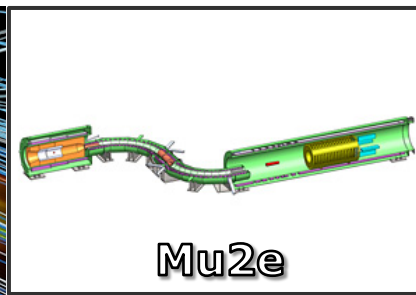
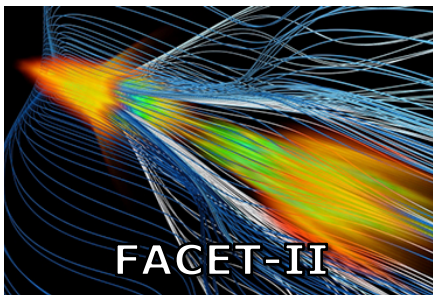
HEP Budget (\$ in thousands)	FY 2017 Enacted	FY 2018 Request	FY 2018 Annualized CR	FY 2019 Request
<b>Research</b>	347,852	272,887		280,130
<b>Facility/ Operations</b>	255,162	213,813		211,020
<b>Projects</b>	221,986	186,000		278,850
<b>Total, HEP</b>	<b>825,000</b>	<b>672,700</b>	<b>819,397</b>	<b>770,000</b>

- ▶ The 2019 President's Budget Request for HEP is an overlay of:
  - ▶ Administration priorities
  - ▶ Office of Science (SC) priorities (interagency partnerships, national labs, accelerator R&D, QIS)
  - ▶ P5 priorities (preserve vision, modify execution)
- ▶ FY19 Budget Request reduces near-term science (research and operations) for P5-guided investments (projects) in mid- and long-term program
  - ▶ All projects continue, some with delays
  - ▶ Research drops below 40% of the program budget to enable executing P5 priority projects
  - ▶ Operations support for ongoing experiments also reduced to make this possible
- ▶ The Administration supports the overall P5 strategy



# FY19 Request: Projects & New Initiatives

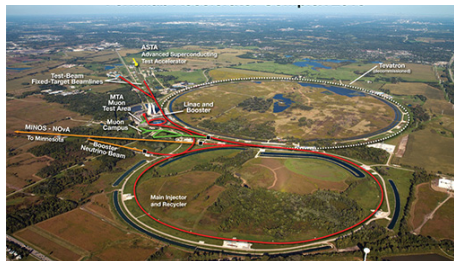
- ▶ Projects receiving final funding in FY 2018: **LSST Camera (LSSTcam)**
- ▶ **Projects fully supported** in FY 2019 according to planned funding profile:
  - ▶ Muon to Electron Conversion (Mu2e)
  - ▶ High-Luminosity Large Hadron Collider (HL-LHC) Accelerator Upgrade Project
  - ▶ **LZ and SuperCDMS-SNOLAB** direct-detection dark matter experiments
  - ▶ **Dark Energy Spectroscopic Instrument (DESI)**
- ▶ Projects adjusted in FY 2019 with respect to profiles in latest DOE Critical Decision:
  - ▶ LBNF/DUNE investment growth slowed; investments made are necessary to enable international contributions
  - ▶ HL-LHC ATLAS and CMS Detector Upgrade projects are minimally adjusted
  - ▶ PIP-II is slowed compared to its CD-0 funding forecast
  - ▶ FACET-II accelerator project will be delayed, requiring coordination with the BES LCLS-II project to plan a new schedule for installation
- ▶ **New initiatives**
  - ▶ HL-LHC ATLAS and CMS Detector Upgrade Projects are new start MIEs in FY 2019





# FY19 Request: Research & Facility Operations

- ▶ In midst of “Building for Discovery,” HEP must keep P5 projects moving forward
  - ▶ FY 2019 Request for Research & Operations adjusted in order to maintain project support
- ▶ **Research:** Higher priority for activities at Labs and Universities that are:
  - ▶ Critical to executing the P5 recommendations
  - ▶ Part of world-leading long-term R&D in Advanced Technology, Accelerator Stewardship, and Quantum Information Science (QIS)
- ▶ **Facility & Experimental Operations**
  - ▶ Funding for the Fermilab Accelerator Complex to operate and support the neutrino and muon experiments including NOvA, the Short Baseline Neutrino program, and Muon g-2
    - Plan 3,600 hours Fermilab Accelerator Complex operations, 75% of optimal
  - ▶ **Cosmic Frontier:** operations of current experiments continues planned ramp-downs, while support ramps-up for P5 projects to carry out pre-operations efforts



# HEP Budget Status: FY17 – FY19



→**FY17:** HEP received \$825M in the FY 2017 Congressional Appropriation, about \$7M above the FY 2017 President's Request

→**FY18:** President's Request for HEP of \$672.7M is guided by priorities of Administration, Office of Science (SC), & 2014 P5 plan

- ▶ U.S. House of Representatives released draft language for the FY 2018 budget in June 2017; U.S. Senate in mid-July 2017
  - Supportive of HL-LHC Accelerator Project, HL-LHC ATLAS and CMS Upgrade projects, LBNF/DUNE, and **Cosmic Frontier projects**
  - Research funding constrained; efforts critical to P5 remain a priority
- ▶ Congressional Marks are budget indicators, but final appropriation bill and report language directs program implementation
- ▶ **Currently on a Continuing Resolution (CR) through 3/23/18.**

→**FY19:** President's Request for HEP of \$770M is guided by priorities of Administration, SC & P5

→Planning the HEP program is challenging due to the significant differences in the Request, House & Senate marks, and short term CRs.



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# Cosmic Frontier Program Areas

→Pursues 4 of the 5 science drivers from the 2014 P5 Strategic Plan

Study dark energy through staged program of complementary surveys (in partnership with NSF-AST) to enable precision measurements that differentiate between cosmological constant, new fields, or modification to General Relativity

- ▶ Imaging: **DES** operating, **LSST** in fabrication phase
- ▶ Spectroscopic: **eBOSS** operating, **DESI** in fabrication

Staged suite of complementary direct-detection experiments with multiple technologies to search for dark matter WIMP and axion particles (with NSF-PHY)

- ▶ High- and low-mass WIMPs: **SuperCDMS-SNOLAB** and **LZ**, in fabrication
- ▶ Axion (ultralow mass) experiment: **ADMX-G2** in operation

Study cosmic acceleration (inflation) at energies near the Planck scale, along with dark energy & neutrino properties, through the cosmic microwave background (CMB) (in partnership with NSF)

- ▶ **SPT-3G** in operation; also research and technology efforts in other experiments
- ▶ Next generation array 10x more sensitive → **CMB-S4** in planning

Use ground-based arrays, space telescopes, and the International Space Station (ISS) to study high-energy cosmic-ray & gamma-ray particles produced by the cosmos – to perform indirect searches for dark matter, study fundamental physics & high energy acceleration mechanisms (in partnership with NSF, NASA)

- ▶ **HAWC (Mexico)**, **Fermi/GLAST (space)**, **AMS (on ISS)** in operation

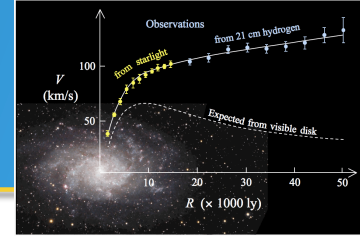
Notes: In addition to NSF and NASA, all experiments and projects have international partners or contributions and some also have private contributions



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# Cosmic Frontier – Program Planning & Priorities; Status



## Priorities aligned with P5:

- **P5 Science priorities: dark matter (direct), dark energy and increased efforts in CMB**
- **P5 Program priorities – Execution of recommended projects**
  - 4 Major Item of Equipment (MIE) projects, 2 small experiments

**Operating experiments** continue to advance & produce science results

- Ones operating more than 2 years being considered by Portfolio Review (Oct 2017 - May 2018): **DES, eBOSS, Fermi-LAT, HAWC, AMS**
- P5-recommended experiments that recently started operations:
  - **ADMX-G2, SPT-3G** (below-MIE projects)

**Projects in Fabrication:** Priority is on executing the 4 P5-recommended MIE projects: **LSSTcam, DESI, LZ, SuperCDMS-SNOLAB**

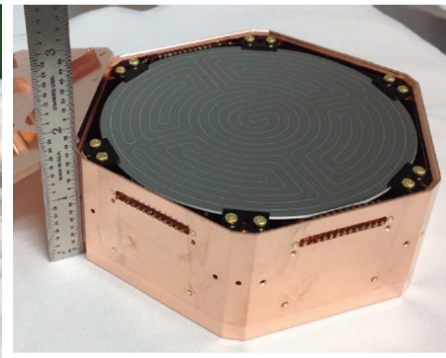
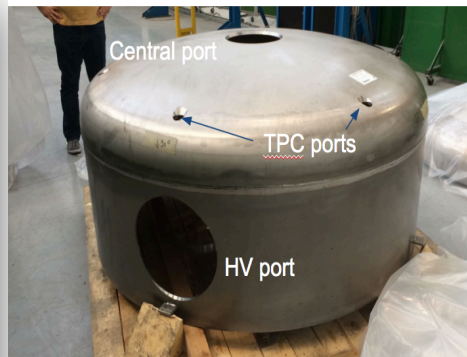
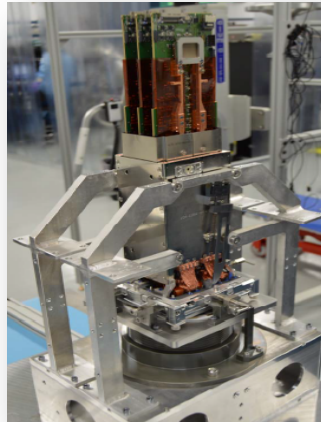
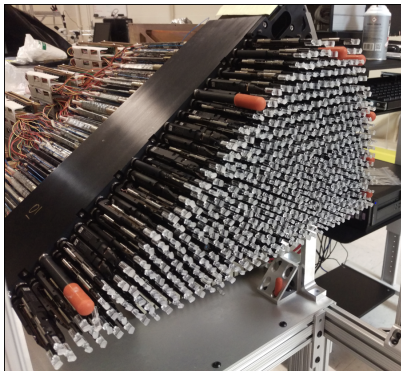
- FY18 Request prioritizes efforts on LZ, slows DESI and SuperCDMS-SNOLAB; House and Senate FY18 Marks address these issues; FY19 Request fully supports MIE funding plan
- Process to plan for Operations Phase has started

**Future Planning:** Laying ground work for the future by planning and investigating directions in P5 science areas, e.g. **CMB-S4** (mainly science studies; limited R&D; Labs efforts using internally-competed Lab-Directed R&D)



# Cosmic Frontier – Major Item of Equipment (MIE) Projects

Experiment	HEP Project \$M	Location	Critical Decision status	Full Operations Start (planned)	Recent Reviews
DESI	56.3	Arizona	CD-3 June.2016	(Jan.2020)	Feb 2018 Project & Ops plan
LSST	168	Chile	CD-3 Aug.2015	(Oct.2022)	Aug. 2017 Project, Dec. 2018 Facility Ops, March 2017 LSST-DESC
LZ	55.5	S. Dakota	CD-3 Feb.2017	(Sept.2020)	Jan 2018 Project & Ops plan
SuperCDMS-SNOLAB	18.6	Canada	CD-2/3 March 2018 (expected)	(mid-2020)	Jan. 2018 Project



LtoR DESI: completed fiber petal  
 LSST: completed raft tower  
 LZ: cryostat vessel  
 SuperCDMS-SNOLAB: izip detector



# Cosmic Frontier – Operating Experiments

Area	Experiment	Location	DOE-HEP lead	Full Operations Start	Recent Reviews	Current Operations plans
CG	AMS	ISS	MIT	May 2011 launch	Portfolio Review	AMS plans operations through 2024
CG	FGST	space	SLAC	June 2008 launch	Portfolio Review	HEP Ops for critical SLAC efforts after FY18
CG	HAWC	Mexico	LANL	March.2015	Portfolio Review	Ops through 2019; HAWC plans to 2023
DE	DES	Chile	FNAL	Sept. 2013	Portfolio Review	Ops through end 2018
DE	eBOSS	New Mexico	Utah	2014	Portfolio Review	HEP support through spring 2018; eBOSS plans through FY19
DM	ADMX-G2	U. Wash	FNAL	Jan.2017	Oct. 2017 Ops Sept. 2014 Project,	Ops through 2020/21 for 0.5 to 2MHz
CMB	SPT-3G	S. Pole	ANL	Feb.2017	Dec. 2014 Ops	Ops through 2021

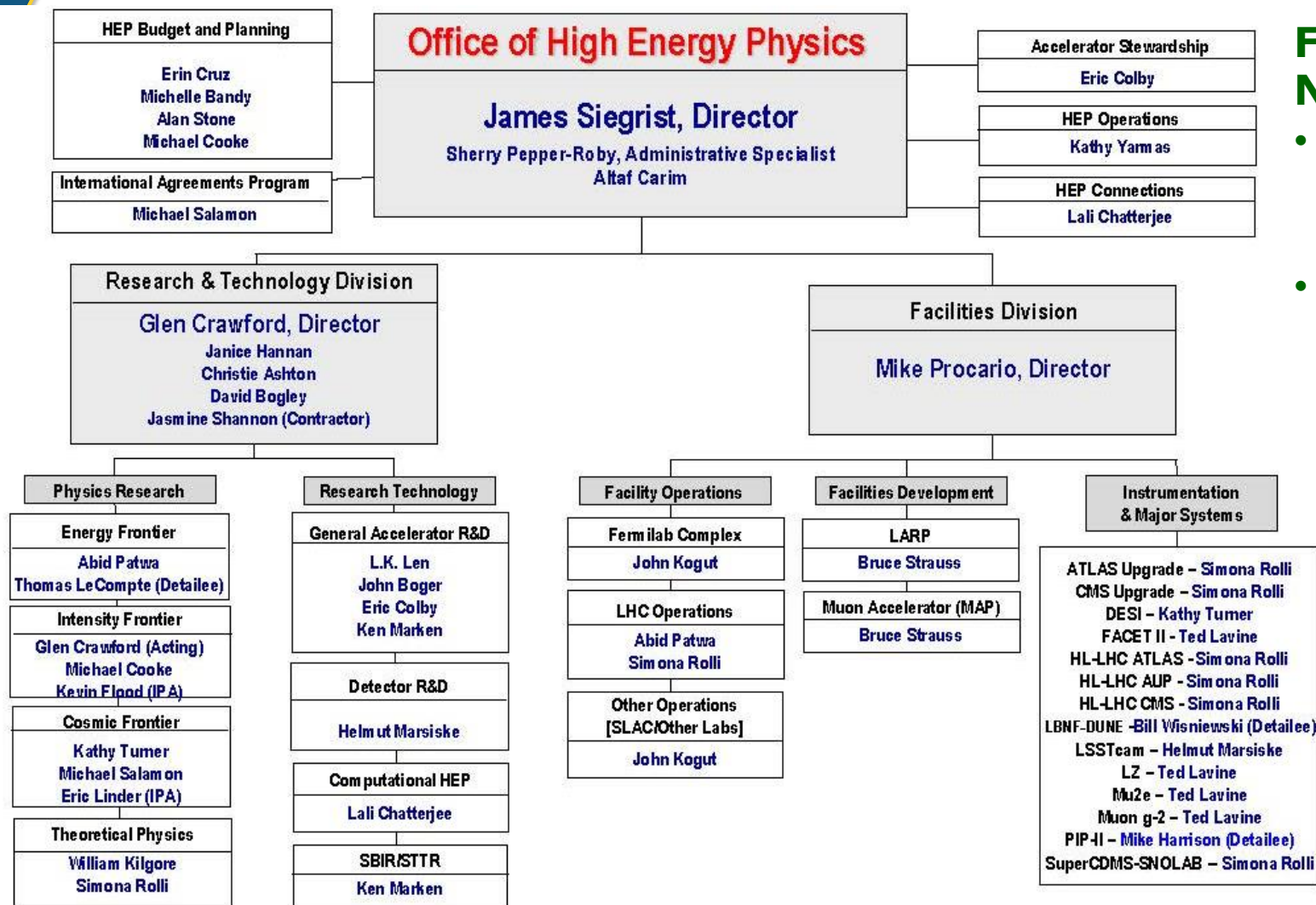
CG = Cosmic-ray, Gamma-ray; DE = Dark Energy; DM=Dark Matter



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# DOE Office of HEP



## Feb.2018 NEWS:

- **Michael Salamon** retiring
- **Karen Byrum** (ANL) joined HEP as a Detailee

HEP underpins and advances the DOE missions and objectives through a balance portfolio of scientific **research**, facilities' **operations** and **projects**, and by the development of **key technologies** and **trained person-power** needed to work at the cutting edge of science.

# Summary & Conclusion

HEP is maintaining the core of the DOE Science Mission and is reflected in FY18 current plan and FY19 Request

- HEP is delivering exciting discoveries, important scientific knowledge, and technological advances
- Program priorities will continue to be driven by the P5's compelling, realistic strategic plan
- Cosmic Frontier has staged program of currently operating experiments, projects in fabrication and planning for the future, to make significant advances aligned with the P5 science drivers.
- HEP looking forward to participation in the National Academy of Science's 2020 Astronomy & Astrophysics Decadal Survey



# BACKUP MATERIAL



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# DOE HEP Portfolio Review 2017-2018

## **HEPAP was charged (Oct. 2017) to carry out a Portfolio Review**

-- Modeled on NSF Portfolio Review and NASA Science Reviews

### Why:

- ▶ Given the current budget outlook, we think it is imperative to take a close and critical look at currently operating HEP experiments and how effectively they are advancing the P5 plan
  - ▶ Portfolio Review is the process we have created to implement this
  - ▶ Overarching goal is to maintain and optimally execute the P5 plan

Note: The Cosmic Frontier has had reviews of operating experiments in the past; what's new is it is now in the context of the entire program.

### What:

- ▶ Independent peer review of currently operating experiments supported by HEP
- ▶ Will focus on scientific impact and productivity of HEP-supported contributions
- ▶ HEP will use the results to define a detailed implementation plan for P5 strategic vision in the FY19 to FY22 timeframe
- ▶ HEP management will ensure that key officials in institutions or agencies that are partners in operating experiments are apprised of the plans for the HEP Portfolio Review as well as resulting decisions.



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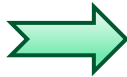
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# DOE HEP Portfolio Review 2017-2018

## HEP Portfolio Review

DOE and NSF issued charge to HEPAP Oct 13, 2017



- Copy of the Charge is available on the HEPAP website
- Requests two subpanels to review currently operating experiments
- Like all HEPAP charges, the charge letter is joint-agency, but reviews will only consider DOE-supported experiments



U.S. Department of Energy  
and the  
National Science Foundation  
OCT 13 2017



Dr. Andrew Lankford  
Chair, HEPAP  
University of California, Irvine  
4129H Frederick Reines Hall  
Irvine, California 92697

Dear Dr. Lankford:

The Department of Energy (DOE) Office of High Energy Physics (HEP) requests that the High Energy Physics Advisory Panel (HEPAP) charge subpanels to conduct an independent peer review of currently operating experiments supported by HEP [hereafter generically referred to as "HEP experiments"]. This review should focus on the scientific impact and productivity of HEP-supported contributions to these experiments within the context of the overall HEP portfolio. HEP will use the findings and recommendations from this review to help further define a detailed implementation plan for the strategic vision laid out in the Particle Physics Project Prioritization Panel ("P5") Report, as recommended by the recent HEP Committee of Visitors.

This review process is modelled in part on similar "Senior Review" or "Portfolio Review" processes employed by the National Aeronautics and Space Administration and the National Science Foundation to maximize the scientific productivity of their respective mission or facility portfolios within realistic budget constraints, with modifications as needed and appropriate for the DOE mission and experimental portfolio. Therefore, this independent review will serve primarily as advice to HEP. Specifically, HEP will use the outcomes from this process to:

- Prioritize the currently operating HEP portfolio of experiments (including contributions to HEP experiments at off-shore facilities);
- Define an implementation approach to best achieve the goals of the P5 science drivers; and
- Provide programmatic guidance to the HEP experiments concerned for FY 2019 and beyond.

Additional outcomes or programmatic guidance for future years may be provided to the experiments at the discretion of HEP management. Actions resulting from this review process could include changes to research support; extending the planned running of a particular experiment; maintaining the status quo; significantly restructuring the run plan; or terminating HEP support for experimental operations. **All currently-supported HEP experiments that have taken physics data for at least two years, and are expected to request significant DOE support for operations, or related activities (e.g., computing) beyond FY 2018 are subject to this review.**



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# DOE HEP Portfolio Review 2017-2018

## Experiments being reviewed:

- ▶ Includes all currently-supported HEP experiments that have taken physics data for at least two years, and are expected to request significant DOE support for operations or related activities (e.g., computing) beyond FY 2018
- ▶ There are 2 separate subpanels:
  1. LHC subpanel is chaired by Hugh Montgomery & covers ATLAS and CMS
  2. "Main" subpanel is chaired by Paul Grannis covers **AMS, Fermi-GLAST, HAWC, DES, eBOSS in the Cosmic Frontier**, along with 8 Intensity Frontier experiments (Daya Bay, KOTO, MicroBooNE, Minerva, NA61/SHINE, NOvA, SuperK, T2K)

## Schedule

- ▶ HEPAP charged Oct. 2017
- ▶ Proposals and materials are due Feb. 1, 2018
- ▶ Subpanels will meet F2F at the end of February & end of March.
- ▶ Reports will be provided to HEPAP for approval in May 2018

## **More information →**

- See Glen Crawford's HEPAP Dec. 2017 Presentation at:  
[https://science.energy.gov/~media/hep/hepap/pdf/201712/Day1/Crawford\\_2017-11-30\\_DOE\\_Portfolio\\_Review.pdf](https://science.energy.gov/~media/hep/hepap/pdf/201712/Day1/Crawford_2017-11-30_DOE_Portfolio_Review.pdf)
- Charge letter, instructions and FAQ at: <https://science.energy.gov/hep/hepap/reports/>



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# HEP Budget Status

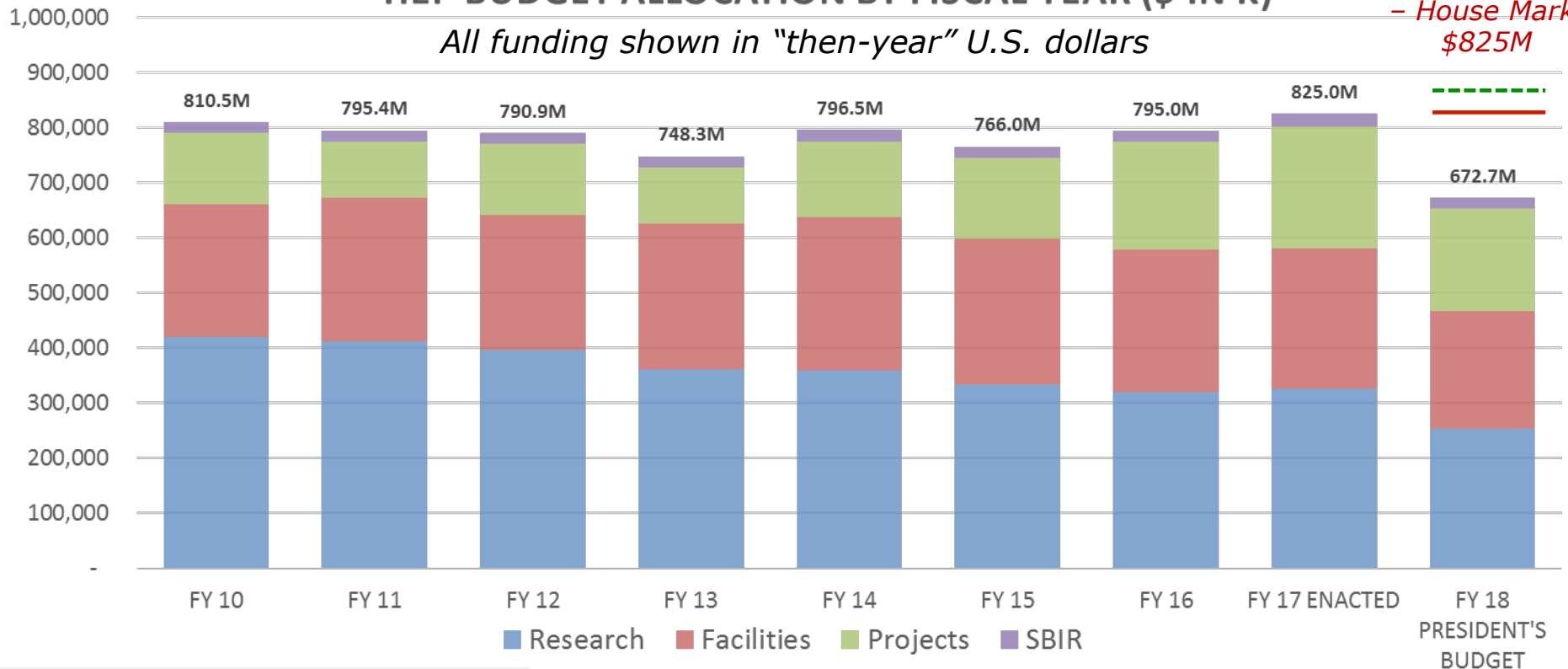
## HEP BUDGET ALLOCATION BY FISCAL YEAR (\$ IN K)

*All funding shown in "then-year" U.S. dollars*

-- Senate Mark:  
\$860M

- House Mark:  
\$825M

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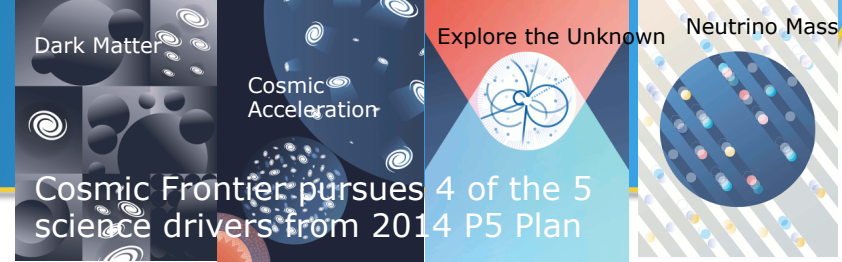
# High Energy Physics Mission & Plan

- ▶ The HEP mission is to understand how our universe works at its most fundamental level:
  - ▶ Discover the most elementary constituents of matter and energy
  - ▶ Probe the interactions between them
  - ▶ Explore the basic nature of space and time
- ▶ In **May 2014, the Particle Physics Project Prioritization Panel (P5) released “Building for Discovery: Strategic Plan for U.S. Particle Physics in the Global Context”**
  - ▶ Long-term strategy enables discovery and maintains the U.S. position as a global leader in particle physics
  - ▶ P5’s five intertwined **science drivers** show great promise for discovery:
    - ▶ 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
  - ▶ **Science drivers** identify the scientific motivation while the **Energy, Intensity, and Cosmic 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	●	●	●



# Cosmic Frontier: P5 Strategic Plan (May 2014) Recommendations



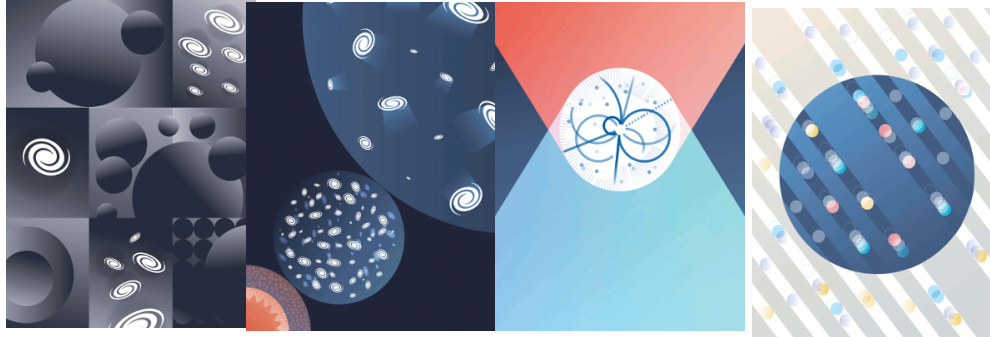
**P5 recommended a complementary suite of projects to advance understanding of the nature of dark matter and dark energy, and to support CMB experiments as part of core program**

- Dark Energy
  - ▶ Complete **LSST** as planned
  - ▶ Build **DESI** as a major step forward in dark energy science
- ▶ Dark Matter (Direct Detection)
  - ▶ Proceed immediately with broad 2<sup>nd</sup> generation dark matter direct detection program (**DM-G2**)
    - ▶ Invest in this program at a level significantly above that called for in the 2012 joint agency announcement of opportunity
  - ▶ Support one or more third-generation (G3) direct detection experiments
    - ▶ Guide G3 by the results of the preceding (G1, G2) searches
    - ▶ Seek a globally complementary program and increased international partnership in G3 experiments (DM-G3 Project is in the P5 plan in later part of their 10 year plan)
- ▶ Cosmic Microwave Background (CMB)
  - ▶ Support CMB experiments as part of the core particle physics program
  - ▶ The multidisciplinary nature of the science warrants continued multi-agency support (CMB-S4 Project is in the P5 plan, starting about mid-way through their 10 year plan)
- ▶ Cosmic Rays and Gamma Rays
  - ▶ Invest in CTA only if the critical NSF Astronomy funding can be obtained
    - CTA has a broad science reach that transcends fields, with the dark matter detection capabilities of direct importance to particle physics; Using P5 Criteria, a de-scoped US component should be shared by NSF-AST, NSF-PHY and DOE.



# Cosmic Frontier Experimental Program

→Pursues 4 of the 5 science drivers from the 2014 P5 Strategic Plan



Dark Matter

Cosmic Acceleration

Explore the Unknown

Neutrino Mass

**Science priorities** are aligned with the 2014 P5 strategic plan:

- P5 recommended a complementary suite of projects to advance understanding of the nature of dark matter and dark energy, and to support CMB experiments as part of core program

## Program Areas:

Dark Energy, Dark Matter, CMB, Cosmic-ray & Gamma-ray experiments

- HEP-related efforts in Theory, Detector R&D, accelerator-based experiments

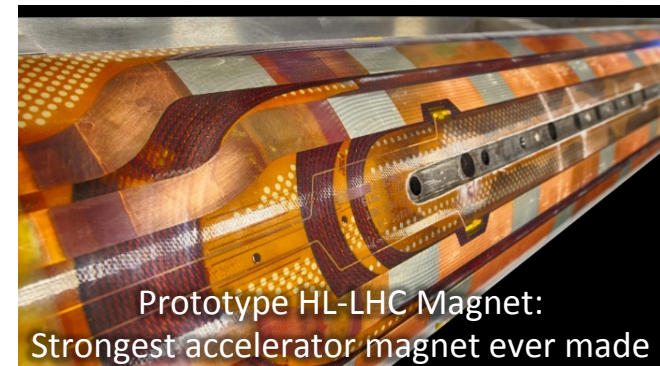
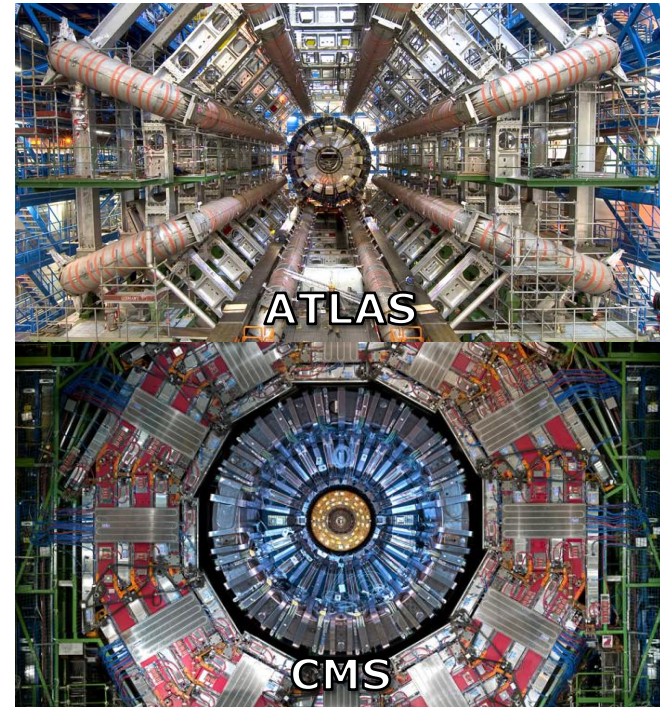


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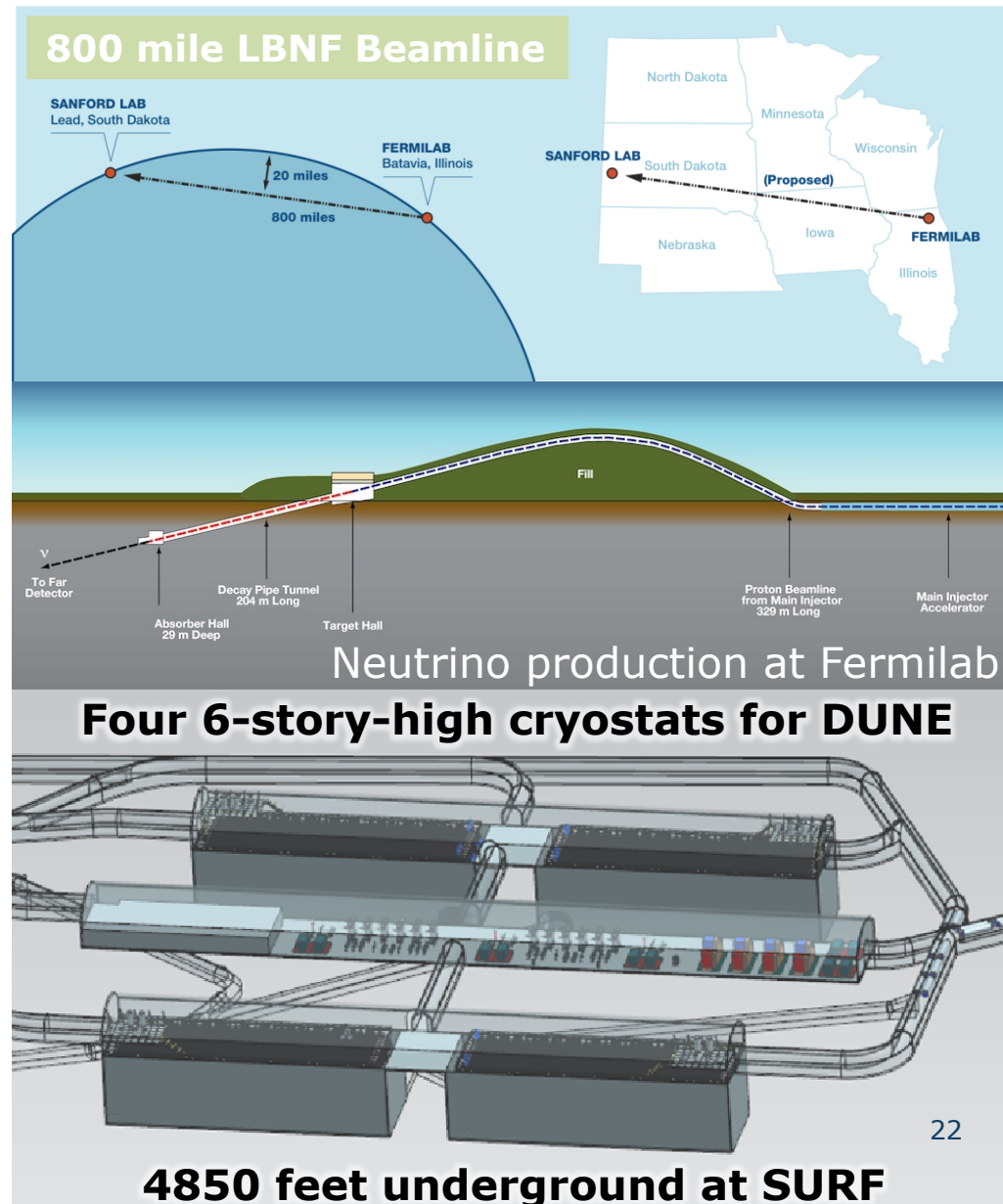
# Energy Frontier Program

- ▶ U.S. investments enable leading roles in LHC collaborations
- ▶ P5 report identified High-Luminosity LHC (HL-LHC) upgrades as one of the highest priority large projects
  - ▶ HL-LHC extends discovery potential by increasing LHC collision rate, enabling detectors to collect a factor of ten more data over another decade
- ▶ U.S. leadership in superconducting magnet technology, and with Nb<sub>3</sub>Sn in particular, is essential to the success of the HL-LHC project
  - ▶ HL-LHC Accelerator Upgrade Project uses this expertise to serve HEP community needs
- ▶ U.S. laboratories and institutions will develop and build major subsystems for the HL-LHC ATLAS and CMS detector upgrades
  - ▶ Detector expertise and support provides foundation for continued U.S. leadership in HL-LHC scientific research program



# Long Baseline Neutrino Facility and Deep Underground Neutrino Experiment

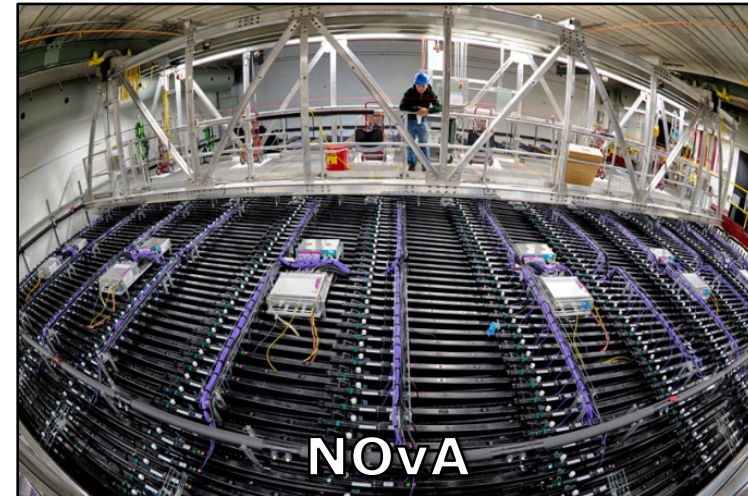
- ▶ P5 recommended the Long Baseline Neutrino Facility (LBNF) as the centerpiece of a U.S.-hosted world-leading neutrino program and highest-priority U.S.-hosted large project
  - ▶ Fermilab working with global partners to establish “mega-science” facility with first physics in the mid-2020s
- ▶ LBNF will produce the world’s most intense neutrino beam and send it 800 miles through the earth
- ▶ DUNE will be a large liquid argon neutrino detector located nearly 1 mile underground at the Sanford Underground Research Facility
  - ▶ DUNE includes over 1,000 collaborators from 174 institutions in 31 countries
- ▶ LBNF/DUNE got CD-3A approval in Sep. 2016, groundbreaking 6/2017
- ▶ PIP-II will increase the beam power for neutrino production at Fermilab from 700 kW to 1,200 kW





# Short-/Long-baseline Neutrino Expts.

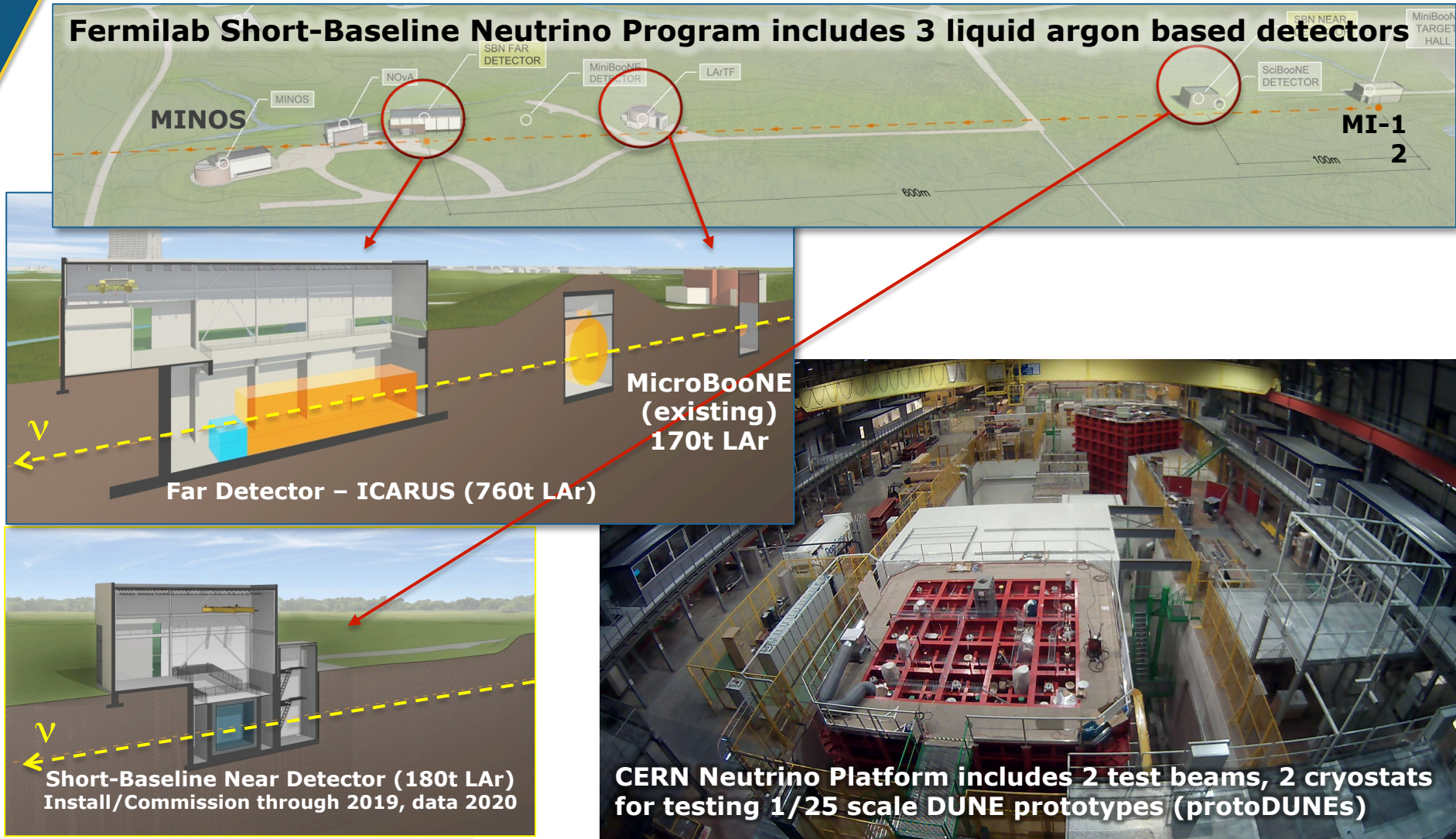
- ▶ NOvA is taking data using the world's most powerful neutrino beam and the world's longest baseline
  - ▶ World's highest intensity neutrino beam sent 500 miles from Fermilab to Ash River, MN
  - ▶ Began six-year run in October 2014
  - ▶ NOvA switched to antineutrino mode in March 2017 based on results from first 2 yrs of data
- ▶ Fermilab Short-Baseline Neutrino Program will advance neutrino physics and demonstrate detector technology for LBNF/DUNE
  - ▶ MicroBooNE began taking data in 2015, is now producing publications
  - ▶ Largest liquid argon neutrino detector in the world, ICARUS, transported from Europe to Fermilab in 2017 for installation in 2018
  - ▶ Short-Baseline Near Detector (SBND) will install/commission through 2019





# Advancing Science & Tech. Towards LBNF/DUNE

## Fermilab Short-Baseline Neutrino Program includes 3 liquid argon based detectors







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