



U.S. DEPARTMENT OF
ENERGY

Office of
Science

High Energy Physics Budget Planning and Execution

High Energy Physics Advisory Panel

May 2018

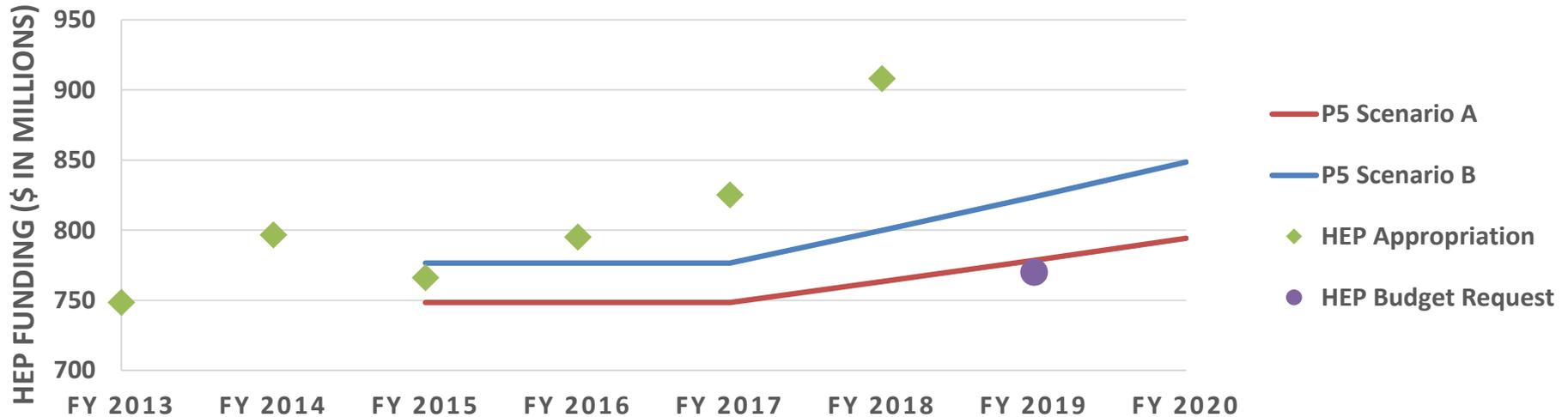
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HEP Budget vs. P5 Scenarios

- ▶ P5 was charged to consider 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
- ▶ FY 2018 Appropriation (\$908M) provides funding for all HEP Projects at their recommended profiles. Facilities and Experimental Operations are supported at their optimal levels. Research is funded above 40% of the total HEP budget.
- ▶ FY 2019 President's Budget Request (\$770M) reflects the P5 vision
 - ▶ Preserves flexibility in situ to continue or ramp down efforts contingent on what Congress appropriates

HEP BUDGET SCENARIOS



Budget Execution for FY 2017

- ▶ From HEP Committee of Visitors 2016 report
 - ▶ *Recommendation 4: Augment discussion with HEPAP of budgets by annually presenting the disposition of reserves and explaining how the final HEP allocations to the research programs of the frontiers are consistent with P5 recommendations.*
- ▶ Budget evolves throughout formulation, appropriation, and execution process
 - ▶ Budget reserves exist across subprograms in the Enacted budget that are allocated across the program throughout the year
 - ▶ Over 150 separate budget reserve allocation actions were made during execution of FY17
 - ▶ Decisions were based on effective implementation of the P5 strategy, but Final allocations reflects the ensemble of 100's of PM decisions
 - ▶ Comparison of final, "Actual" funding levels most appropriately shows evolution of program
 - ▶ However volatility on the few % level is to be expected



Example of Research Program Variability

- ▶ HEP supports ~250 ongoing research grants through annual Comparative Review
 - ▶ About 1/3 of these come up for renewal each year
 - ▶ Average success rate for renewals is about 80% → about 15 are not renewed each year.
 - ▶ Therefore the annual grant “replacement rate” is 5-7%.
 - ▶ In addition existing grants may not be renewed at same funding level.
- ▶ Plus supplemental and misc. awards via the DOE/SC open solicitation, typically \$1-2M/yr total
- ▶ In addition there are now several dedicated FOAs which account for a few % of total HEP research budget: Early Career, Accel. Stewardship, QIS. These impact the overall HEP Research budget but have a different mission focus.
- ▶ Therefore it is very difficult to discern Research funding trends at the few % level



FY 2017 Program Execution

- ▶ Major FY16 to FY17 changes supported ramp-up of P5 projects
 - ▶ HL-LHC, LBNF/DUNE, Mu2e, DM-G2, LSST
- ▶ Facilities Operations sustained support for ongoing experiments
- ▶ Research increases focused efforts critical to implementing the P5 strategy
 - ▶ FY17 include planned increase for LHC Accelerator Directed R&D (LARP) for pre-HL-LHC R&D

HEP Funding Category (\$ in K)	FY 2016 Actual	FY 2017 Enacted	FY 2017 Actual	FY 2017 Actual vs. FY 2017 Enacted	FY 2017 Actual vs. FY 2016 Actual
Research (<i>with SBIR/STTR</i>)	341,663	347,852	344,043	-3,809	+2,380
<i>Laboratory Research</i>	209,564	217,849	214,217	-3,632	+4,653
<i>University Research</i>	111,252	107,724	107,675	-49	-3,577
Facilities/Operations	258,236	255,162	258,696	+3,534	+460
Projects	195,101	221,986	222,261	+275	+27,160
Total	795,000	825,000	825,000	---	+30,000



FY 2017 Research Program

- ▶ Intensity Frontier increase driven by additional support for research efforts necessary to support growing program across the lab complex
- ▶ Long-term R&D in GARD, Detector R&D, and Accelerator Stewardship supported as priorities

HEP Research Funding by Subprogram (\$ in K)	FY 2016 Actual	FY 2017 Enacted	FY 2017 Actual	FY 2017 Actual vs. FY 2017 Enacted	FY 2017 Actual vs. FY 2016 Actual
Energy Frontier	73,505	74,911	72,268	-2,643	-1,237
Intensity Frontier	54,683	55,245	56,317	+1,072	+1,634
Cosmic Frontier	47,326	48,750	45,990	-2,760	-1,336
Theoretical Physics	48,615	48,429	47,789	-640	-826
Computational HEP	8,829	7,696	7,924	+228	-905
Advanced Technology R&D	82,215	83,839	83,334	-505	+1,119
Accelerator Stewardship	5,643	6,703	8,270	+1,567	+2,627
Total (no SBIR/STTR)	320,816	325,573	321,892	-3,681	+1,076



FY 2018 Status

- ▶ Lateness of FY2018 Appropriation and attendant budget uncertainties have delayed most HEP budget actions
 - ▶ HEP still does not have full FY18 budget authority, as DOE CFO has only released 30-day allotments for Apr and May
 - ▶ Initial emphasis was on keeping Projects going at planned pace and Facilities operating
 - ▶ Large uncertainties in final FY18 funding level caused HEP to hold off on funding most grants until after Appropriation
- ▶ Now, we are faced with a year's worth of funding actions in ~4 months:
 - ▶ 250 comparative review grants
 - ▶ ~30 supplemental and misc grants
 - ▶ Of order 10 (each) : Early Career, US-Japan, Accel Stewardship, QIS
 - ▶ Over 100 lab supplemental funding requests
- ▶ We are addressing these as quickly as possible



FY 2019 President's Budget Request



FY 2019 President's Budget Request

HEP Funding Category (\$ in K)	FY 2017 Actual	FY 2018 Enacted	FY 2019 Request	FY 19 vs. FY 18
Research	344,043	369,565	280,130	-89,435
Facilities/Operations	258,696	260,535	211,020	-49,515
Projects	222,261	277,900	278,850	+950
Total	825,000	908,000	770,000	-138,000

- ▶ The 2019 President's Budget Request for HEP is an overlay of:
 - ▶ Administration priorities
 - ▶ SC priorities (interagency partnerships, national laboratories, accelerator R&D, QIS)
 - ▶ P5 priorities (preserve vision, modify execution)
- ▶ FY19 Budget Request reduces near-term science for P5-guided investments in mid- and long-term program
 - ▶ "Building for Discovery" by supporting highest priority P5 projects to enable future program
 - ▶ Research support advances P5 science drivers and world-leading, long-term R&D in Advanced Technology, Accelerator Stewardship, and Quantum Information Science
 - ▶ Operations support enables world-class research at HEP User Facilities
- ▶ The administration supports the overall P5 strategy

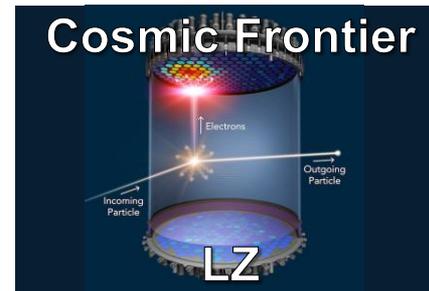
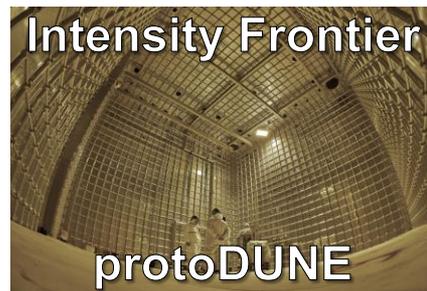


FY 2019 Budget Highlights: Frontiers

- ▶ **Energy Frontier:** Actively engage in successful LHC program and HL-LHC upgrades
 - ▶ The 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

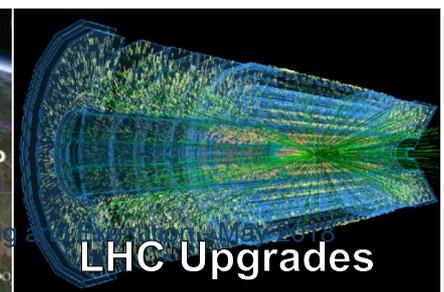
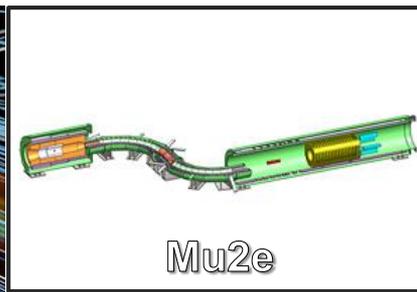
- ▶ **Cosmic Frontier:** Advance our understanding of dark matter and dark energy
 - ▶ P5 recommended complementary suite of projects to search for dark matter candidates and study dark energy; request supports full planned profile for LZ, SuperCDMS-SNOLAB, DESI



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

FY 2019 Projects and 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 reviews:
 - ▶ 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



FY 2019 Research and Facility Operations

- ▶ In midst of “Building for Discovery,” must keep P5 projects moving forward
 - ▶ FY 2019 Request for Research and Facilities Ops adjusted in order to maintain project support
- ▶ Higher priority given to research 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)
- ▶ Request includes funding for the Fermilab Accelerator Complex to operate and support the neutrino and muon experiments
 - ▶ Funding will prioritize delivering the particle beams and providing experimental operations for ongoing experiments, including NOvA, the SBN program, and Muon g-2
 - ▶ Plan 3,600 hours of operations for Fermilab Accelerator Complex, 75% of optimal 4,800 hours



FY 2019 Funding by Subprogram

▶ Research/Facilities/Project breakdown in following slides

HEP Funding Category (\$ in K)	FY 2017 Actual	FY 2018 Enacted	FY 2019 Request	FY 19 vs. FY 18
Energy Frontier	154,274	190,938	181,232	-9,706
Intensity Frontier	242,924	246,768	200,170	-46,598
Cosmic Frontier	135,988	121,246	75,446	-45,800
Theoretical and Computational Physics	60,251	78,156	73,980	-4,176
Advanced Technology R&D	124,447	114,962	83,755	-31,207
Accelerator Stewardship	13,616	15,530	12,417	-3,113
Construction (Line Item)	93,500	140,400	143,000	+2,600
Total	825,000	908,000	770,000	-138,000



Energy Frontier

- ▶ **Research:** higher priority to support laboratory research activities to address the Higgs boson science driver, and to carry out the final analyses on data taken prior to LHC LS2 in 2019-20
- ▶ **Facility Operations:** focus on commissioning of LHC ATLAS and CMS Detector Upgrade projects. Reduced support for compute nodes, data storage due to lower demand during LS2
- ▶ **Projects:** increase supports new MIE starts for the HL-LHC ATLAS and HL-LHC CMS Detector Upgrade Projects and the planned increase for the HL LHC Accelerator Upgrade Project

Energy Frontier (\$ in K)	FY 2017 Actual	FY 2018 Enacted	FY 2019 Request	FY 19 vs. FY 18
Research	72,268	79,530	56,119	-23,411
Facilities/Operations	52,771	54,340	44,309	-10,031
Projects	24,017	51,000	77,000	+26,000
<i>LHC ATLAS Upgrade</i>	8,500	-	-	---
<i>LHC CMS Upgrade</i>	7,967	-	-	---
<i>HL-LHC Accelerator Upgrade</i>	500	27,000	42,000	+15,000
<i>HL-LHC ATLAS Upgrade</i>	4,300	12,000	17,500	+5,500
<i>HL-LHC CMS Upgrade</i>	2,750	12,000	17,500	+5,500
SBIR/STTR	5,218	6,068	3,804	-2,264
Total	154,274	190,938	181,232	-9,706



Intensity Frontier

- ▶ **Research:** higher priority to support laboratory research activities to address the neutrino mass and explore the unknown science drivers, and to carry out the early physics data analyses from Muon g-2, Belle II, SBN program and protoDUNE.
- ▶ **Facility Operations:** activities will prioritize delivering the particle beams and providing experimental operations for ongoing experiments, including NOvA, SBN program, and Muon g-2. The Fermilab Accelerator Complex will be running at 75% of optimal levels.
- ▶ **Projects:** focus on preliminary design and prototyping for the PIP-II project. OPC will continue for LBNF/DUNE for plant support costs.

Intensity Frontier (\$ in K)	FY 2017 Actual	FY 2018 Enacted	FY 2019 Request	FY 19 vs. FY 18
Research	56,317	60,700	41,246	-19,454
Facilities/Operations	154,301	153,385	125,916	-27,469
Projects	24,569	24,100	26,000	+1,900
<i>LBNF/DUNE</i>	-	1,000	1,000	---
<i>PIP-II</i>	15,220	23,100	25,000	+1,900
<i>Muon G-2</i>	6,349	-	-	---
SBIR/STTR	7,737	8,583	7,008	-1,575
Total	242,924	246,768	200,170	-46,598



Cosmic Frontier

- ▶ **Research:** higher priority to support laboratory research activities to address the dark matter and dark energy science drivers, and to carry out the final data analyses on Cosmic Frontier experiments completing in FY 2019
- ▶ **Facility Operations:** focus on the installation, commissioning and pre-operations activities for LSSTcam, DESI, LZ, and SuperCDMS-SNOLAB as these projects transition to operations
- ▶ **Projects:** priority to support the fabrication and installation of the DESI, LZ, and SuperCDMS-SNOLAB projects. LSSTcam project funding will conclude as planned

Cosmic Frontier (\$ in K)	FY 2017 Actual	FY 2018 Enacted	FY 2019 Request	FY 19 vs. FY 18
Research	45,990	49,892	31,506	-18,386
Facilities/Operations	13,353	16,310	11,320	-4,990
Projects	74,375	52,400	30,850	-21,550
<i>LSSTcam</i>	45,000	9,800	-	-9,800
<i>DESI</i>	12,800	20,000	11,400	-8,600
<i>LZ</i>	12,500	14,100	14,450	+350
<i>SuperCDMS</i>	3,400	7,400	5,000	-2,400
SBIR/STTR	2,270	2,644	1,770	-874
Total	135,988	121,246	75,446	-45,800



Theoretical and Computational Physics

- ▶ **Theory Research:** higher priority to research that addresses the neutrino mass science driver
- ▶ **Computational HEP:** priority to advance computing research for HEP needs, and working with ASCR to optimize the high performance computing
- ▶ **Quantum Information Science:** focus on research techniques and algorithms, foundational concepts relating particle physics and QIS, quantum computing for HEP experiments and modeling, development and use of specialized quantum controls and precision sensors

Theoretical and Computational Physics (\$ in K)	FY 2017 Actual	FY 2018 Enacted	FY 2019 Request	FY 19 vs. FY 18
Research	55,713	75,303	71,280	-4,023
<i>Theoretical Physics</i>	44,848	43,000	32,753	-10,247
<i>Computational HEP</i>	7,924	8,500	7,435	-1,065
<i>Quantum Information Science</i>	-	18,000	27,500	+9,500
Projects	2,300	-	-	---
SBIR/STTR	2,238	2,853	2,700	-153
Total	60,251	78,156	73,980	-4,176



Advanced Technology R&D

- ▶ **General Accelerator R&D:** priority to world-leading efforts supported at national laboratories
- ▶ **Directed Accelerator R&D:** funding reduced as LARP goals will have been met
- ▶ **Detector R&D:** near-term R&D activities will be ramped down
- ▶ **Facility Operations:** focus on accelerator, test beam, and detector facilities at Fermilab. Funding for LBNL, SLAC supports highest priority research and fabrication activities. LBNL BELLA Second Beamline AIP begins, offset by completion of SLAC Sector 10 Injector Infrastructure AIP
- ▶ **Projects:** focus on critical FACET-II infrastructure to be installed during shutdown for LCLS-II

Advanced Technology R&D (\$ in K)	FY 2017 Actual	FY 2018 Enacted	FY 2019 Request	FY 19 vs. FY 18
Research	83,334	70,757	53,283	-17,474
<i>GARD</i>	44,357	44,500	36,544	-7,956
<i>LARP</i>	21,800	5,000	-	-5,000
<i>MAP</i>	1,000	-	-	---
<i>Detector R&D</i>	16,177	17,000	13,690	+9,500
Facilities/Operations	33,403	30,500	25,525	-4,975
Projects (<i>FACET-II</i>)	3,500	10,000	2,000	-8,000
SBIR/STTR	4,210	3,705	2,947	-758
Total	124,447	114,962	83,755	-31,207



Accelerator Stewardship

- ▶ **Research:** priority will be given to long-term R&D for the science and technology needed to build future generations of accelerators.
- ▶ **Facility Operations:** ATF II Upgrade AIP completion partially offset by the start of the 20TW CO₂ Laser Upgrade AIP

Accelerator Stewardship (\$ in K)	FY 2017 Actual	FY 2018 Enacted	FY 2019 Request	FY 19 vs. FY 18
Research	8,270	9,000	8,032	-968
Facilities/Operations	4,868	6,000	3,950	-2,050
SBIR/STTR	478	530	435	-95
Total	13,616	15,530	12,417	-3,113



Line Item Construction

- ▶ **LBNF/DUNE**: funding will continue for far site civil construction for the excavation of the caverns
- ▶ **Mu2e**: FY 2019 will be last year of funding for the project
- ▶ **PIP II**: project engineering and design funding was initiated in the FY 2018 enacted appropriation

Construction (Line Item) (\$ in K)	FY 2017 Actual	FY 2018 Enacted	FY 2019 Request	FY 19 vs. FY 18
LBNF/DUNE	50,000	95,000	113,000	+18,000
Mu2e	43,500	44,400	30,000	-14,400
PIP-II	-	1,000	-	-1,000
Total	93,500	140,400	143,000	+2,600



Budget Process

- ▶ The FY 2019 President's Budget Request will enable continued implementation of the P5 strategy
 - ▶ All P5 priority projects are supported in the Request
 - ▶ Request reduces near-term science for P5-guided investments in mid- and long-term program
- ▶ Congressional appropriation process is now underway
 - ▶ FY 2018 appropriation enabled advancing P5 priority projects faster than schedule suggested by President's Budget Request
 - ▶ Final FY 2019 appropriation will define continued pace of P5 project execution





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FY 2017 Program Execution

HEP Funding Category (\$ in K)	FY 2016 Actual	FY 2017 Enacted	FY 2017 Actual	FY 2017 Actual vs. FY 2017 Enacted	FY 2017 Actual vs. FY 2016 Actual
Energy Frontier	154,028	156,533	154,274	-2,259	+246
Intensity Frontier	246,817	240,648	242,924	+2,276	-3,893
Cosmic Frontier	131,220	137,815	135,988	-1,827	+4,768
Theoretical and Computational Physics	61,536	60,331	60,251	-80	-1,285
Advanced Technology R&D	124,825	122,082	124,447	+2,365	-378
Accelerator Stewardship	10,474	14,091	13,616	-475	+3,142
Construction (Line Item)	66,100	93,500	93,500	---	+27,400
Total	795,000	825,000	825,000	---	+30,000

