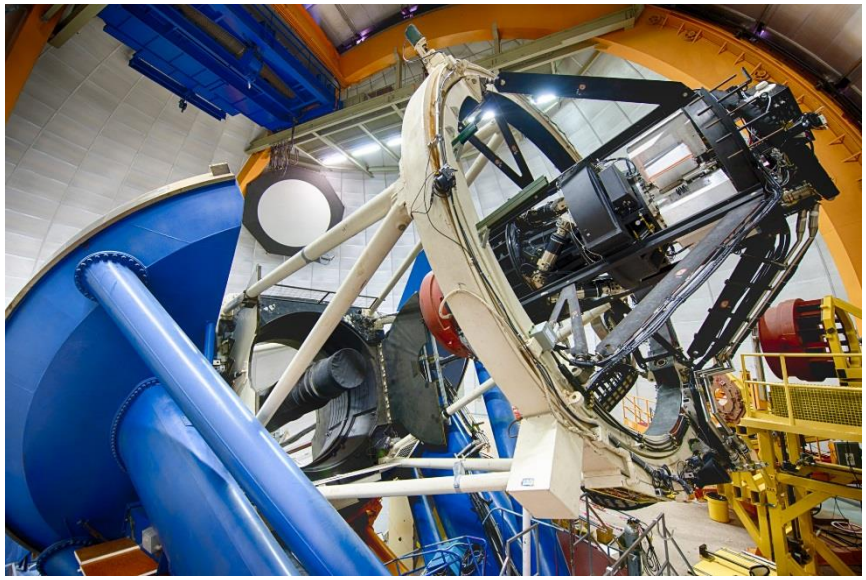
DOE High Energy Physics (HEP) Cosmic Frontier (CF)

report to

AAAC

6 June 2016

Eric Linder



Dark Energy Survey: DECam on CTIO Blanco telescope.

HEP Cosmic Frontier Program Managers:
Anwar Bhatti (IPA), Eric Linder (IPA), Michael Salamon, Kathy Turner

Outline

- Budgets
- Program Status
- Research Proposal Statistics
- 2015-16 AAAC Report and DOE
- Interagency efforts

FY2016 Budget Notes

The FY16 budget was approved on 12/16/15

- The enacted FY16 Budget for HEP of **$795M** (12/16/15) is above the Request & squarely in P5's scenario B.

Cosmic Frontier MIE projects:

- **LSST funded according to its planned profile.**
- **DESI funded at $5.0M more than requested in FY16 (budget guidance)**
- **LZ funded at $1.5M more than requested in FY16 (budget guidance)**
- **SuperCDMS-SNOLAB funded at $1.0M over the requested amount.**

Research budgets:
Even though the FY16 approved budget is more than the requested amount, due to the budget guidance we received and other constraints, the research budget is still constrained and reduced a few % overall.

FY2017 Budget Notes

FY 2017 President's Request ($818M) aims to continue the successful implementation of the P5 strategy

- Investing in portfolio of high-priority projects at the small, medium, and large cost scales
- Request is carefully balanced between support for projects ($212M), facility operations ($252M), and scientific research ($354M) in order to produce scientific results while "building for discovery"

As recommended by P5, a complementary suite of MIE projects will address dark matter and dark energy - continue their fabrication activities at the planned levels.

- **Planned fabrication funding increase supports LSSTcam ($45M), DESI ($10M), LZ ($10.5M), and SuperCDMS-SNOLab ($4M)**

Cosmic Frontier Projects:

FY15 - ***45,203*** FY16 - ***66,835*** enacted (**67,695** current) FY17 (PRB) - ***70,200***

***** Project funding includes MIE, small project fabrication and future project R&D

FY17 House Appropriations (4/19/16): HEP $823M, LSST ($45M), DESI ($12M), LZ ($12.5M)

FY17 Senate Appropriations (5/12/16): HEP $833M, LSST ($45M), DESI ($12M), LZ ($12.5M)

HEP Cosmic Frontier Experiments

March 2016

Activity	Location	Science	Current Status (HEP effort)	# Collaborators	# Institutions	# Countries
Baryon Oscillation Spectrosopic Survey (BOSS)	APO in New Mexico	dark energy stage III (spectroscopic)	operations ended in FY14	230 (150 US, 40 HEP)	(22 US, 8 HEP)	7
extended BOSS (eBOSS)	APO in New Mexico	dark energy stage III (spectroscopic)	Survey started July 2014 (HEP$ started FY15)	229 (100 US, 34 HEP)	54 (29 US, 8 HEP)	12
Dark Energy Survey (DES)	CTIO in Chile	dark energy stage III (imaging)	operations started Sept. 2013	300	25 (13 US, 9 HEP)	7
Large Synoptic Survey Telescope (LSST) - Dark Energy Science Collaboration (DESC)	Cerro Pachon in Chile	dark energy stage IV (imaging)	science studies, planning	232 (200 US, 134 HEP)	53 (41 US, 16 HEP)	3
Large Synoptic Survey Telescope (LSST) - LSSTcam Project	Cerro Pachon in Chile	dark energy stage IV (imaging)	FY14 Fab. start; CD2 Jan 2015; CD3 Aug 2015	142 (111 US, 111 HEP)	17 (11 US, 11 HEP)	3
Dark Energy Spectroscopic Instrument (DESI)	KPNO in AZ	dark energy stage IV (spectroscopic)	FY15 fab start; CD2 approved Sept 2015; CD3 review May 2016	179 (93 US, 74 HEP)	39 (21 US, 19 HEP)	9
DM-G1: Axion Dark Matter eXperiment (ADMX-IIa)	Univ Washington	dark matter - axion search	operations ended 2015	24 (20 US, 17 HEP)	7 (6 US, 3 HEP)	2
DM-G1: Chicagoland Observatory for Underground Particle Physics (COUPP/PICO)	SNOLab in Canada	dark matter - WIMP search	operating through 2016	60 (26 US, 8 HEP)	14 (6 US, 1 HEP)	5
DM-G1: DarkSide-50	LNGS in Italy	dark matter - WIMP search	operating through 2016	146 (52 US, 10 HEP)	32 (14 US, 2 HEP)	7
DM-G1: Large Underground Xenon (LUX)	SURF in South Dakota	dark matter - WIMP search	operating through 2016	102 (86 US, 64 HEP)	19 (15 US, 13 HEP)	4
DM-G1: Super Cryogenic Dark Matter Search (SuperCDMS-Soudan)	Soudan in Minnesota	dark matter - WIMP search	operating through 2016	83 (72 US, 44 HEP)	20 (17 US, 7 HEP)	3
DM-G2: ADMX-G2	Univ Washington	dark matter - axion search	fabrication started end FY14; completing 2016	23 (21 US, 18 HEP)	8 (7 US, 4 HEP)	2
DM-G2: SuperCDMS-SNOLAB	SNOLab in Canada	dark matter - WIMP search	FY15 fab start; CD1 December 2015	90 (74 US, 47 HEP)	22 (17 US, 7 HEP)	5
DM-G2: LZ	SURF in South Dakota	dark matter - WIMP search	FY15 fab start; CD1 April 2015; CD2/3b review April 2016	154 (118 US, 107 HEP)	31 (18 US, 17 HEP)	5
SPT-polarization (SPT-pol)	South Pole	CMB stage 2	operating through 2016	66 (54 US, 8 HEP)	23 (7 US,4 HEP)	5
SPT-3G	South Pole	CMB stage 3	HEP fabrication start in FY15; ends 2016	66 (54 US, 8 HEP)	23 (7 US, 4 HEP)	5
Very Energetic Radiation Imaging Telescope Array System (VERITAS)	FLWO in AZ	gamma-ray survey	operating through 2017	109 (76 US, 28 HEP)	20 (16 US, 5 HEP)	4
Pierre Auger Observatory	Argentina	cosmic-ray	operating through 2016 (2014 PO moved from FNAL to Germany)	436 (61 US, 18 HEP)	90 (17 US, 6 HEP)	17
Fermi Gamma-ray Space Telescope (FGST) Large Area Telescope (LAT)	space-based	gamma-ray survey	June 2008 launch; operating at least through FY18	362 (153 US, 58 HEP)	115 (38 US, 3 HEP)	22
Alpha Magnetic Spectrometer (AMS-02)	space-based (on ISS)	cosmic-ray	May 2011 launch; operating	600	60 (6 US, 2 HEP)	16
High Altitude Water Cherenkov (HAWC)	Mexico	gamma-ray survey	Full science operations started March 2015	111 (54 US, 8 HEP)	28 (17 US, 3 HEP)	3

Cosmic Frontier: Project Advances in the Last Year

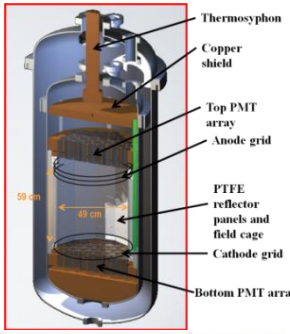
All 4 Cosmic Frontier Major Item of Equipment (MIE) fabrication projects have passed new milestones in the last year:

Dark Energy Spectroscopic Instrument (DESI) - Dark Energy Stage IV spectroscopic

- **CD-2 (Baseline of Scope, Cost & Schedule) approved September 2015**
- **CD-3 (Start of full fabrication activities) reviewed in May 2016**

Large Synoptic Survey Telescope (LSST) – Dark Energy Stage IV Imaging

- **CD-3 for LSST-camera approved August 2015, LSST status review Feb. 2016**

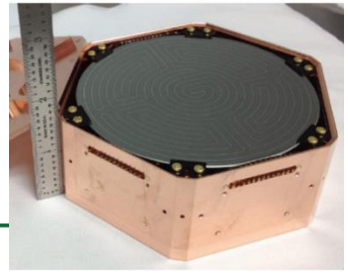


Large Underground Xenon – Zeplin (LZ) - WIMP dark matter search

- **CD-1/3a (Approve alternative selection/long lead fabrication) approved April 2015**
- **CD-2/3b reviewed in April 2016**

Super Cryogenic Dark Matter Search at SNOLab (SuperCDMS-SNOLab) - WIMP search

- **CD-1 approved December 2015; CD-2/3 review planned in 2017**



Cosmic Microwave Background

Gain insight into the inflationary epoch at beginning of universe
- **Probe dark energy, neutrino properties from CMB lensing (by cosmic structure)**
- **B mode polarization power spectrum starting to be mapped**
- **Probe high energies ~10^{12} x LHC, Planckian fields**

Stage 2 (2009-15) – Planck satellite (74 detectors), ground-based (~1000 det.);
Stage 3 (2016-20) – SPT-3G, POLARBEAR/Simons Array, AdvACT (~20000 det.);
Stage 4 ground based – unified into CMB-S4 (~500,000 detectors)

→**CMB-S4 (community led) collaboration is planning an array of telescopes in Chile & the South Pole with participation by DOE labs and universities; bringing together the major S3 collaborations**

→**Technology mature: needs scale-up of detector fab/test, readout.**

HEP has been involved at a low level in CMB for decades (1977 LBNL measures CMB dipole; 1992 COBE → 2006 Nobel Prize), esp. in technology and computing. Now funding SPT-3G camera, several research-only efforts.

- **HEP Cosmic Visions CMB group coordinating HEP efforts**
- **CMB-S4 Community draft Science Book (165 pages)**
  - recent workshop at LBNL w/180 attendees
- **As recommended by P5, HEP is planning to participate in CMB-S4**
- **DOE and NSF agency coordination group meetings**

- **May 2016: Simons Observatory –** $45M from Simons, Heising-Simons, LBL, Penn, Princeton, UCB, UCSD. Doubling # of telescopes/detectors at Atacama, infrastructure.

Cosmic Frontier – Experimental Research Support

FY16 University Research Comparative Review

Proposals	
Received	43
Declined Without Review	7
Reviewed	36 (21)
Funded	21 (8)
"Success Rate" (%) (Previous/New)	58 (87/38)

Investigators	
Received	65
Declined Without Review	10
Reviewed	55 (34)
Funded	25 (9)
"Success Rate" (%) (Previous/New)	45 (76/26)

Junior Faculty	
Reviewed	11 (10)
Funded	4 (4)
"Success Rate" (%) (Previous/New)	36 (0/40)

Proposals: FY16 renewal funding	
Up	5
Flat	6
Down	2
No-Fund	2

FY16 vs FY15:

Proposals reviewed: 36 vs 27
Success rate: 58% vs 52% (5 year avg 60%)
Request: $26.5 vs $21.9M (life of grant)
Request: $7.8M vs $6.8M (Year 1)
Funded: $4.3M vs $3.3M (Year 1 with FFF)

Cosmic Frontier – Statistics on Early Career Awards

	FY10	FY11	FY12	FY13	FY14	FY15	FY16
# received - Univ	11	8	12	16	6	7	7
# received - Lab	10	4	7	9	7	5	6
# funded - Univ	**2**	**1**	**2**	**1**	**1**	**0**	**1**
# funded - Lab	**0**	**2**	**1**	**1**	**0**	**0**	**0**

Awards (5-year):

FY10
Newman (Pitt)
Mahapatra (TAMU)

FY11
Chou (FNAL)
Slosar (BNL)
Hall (Maryland)

FY12
Mandelbaum (CMU)
Padmanabhan (Yale)
Carosi (LLNL)

FY13
Bolton (Utah)
Chang (ANL)

FY14
Dahl (Northwestern)

FY15: none

FY16
Rozo (Arizona)

2015-16 AAAC Annual Report and DOE

Interagency Coordination and Cooperation

FINDING: *Some unique information in the high quality data that will be obtained in several future surveys— particularly LSST, Euclid, and WFIRST— will be significantly enhanced by combining their analysis at an early "pixel" stage, rather than a more highly reduced catalog stage.*
RECOMMENDATION: *Where it can improve overall science productivity and efficiency, cooperation in database design and data sharing is encouraged among US agencies, international agencies, and scientific collaborations.*

TriAgency/TriProject Group meets monthly to discuss DOE/NASA/NSF cooperation on Euclid/LSST/WFIRST, in particular Joint Data Processing and Joint Simulations.

FINDING*: With its history of successes funded by NASA, NSF, and DOE, CMB science crosses the boundaries of agencies. Third generation ground-based efforts and suborbital payloads are now reaching the sensitivity that could enable ground-breaking discoveries of CMB B-modes.*
FINDING: *The scientific community studying the cosmic microwave background has made significant progress on a unified strategy for a fourth generation, ground-based survey of the Universe ("CMBS4"), orders of magnitude more capable than current experiments, with enormous potential for new scientific discovery. A larger role of DOE coordinated with NSF is important to realize the great scientific potential of CMB-S4.*
RECOMMENDATION: *We encourage DOE, NSF, and the university community to continue working toward a plan for a future (Stage 4) ground-based CMB experiment.*

DOE is planning to participate in CMB-S4 and regularly discusses coordination with NSF.

Cosmic Frontier - Interagency Activities, etc.

Interagency Coordination:

- We always coordinate efforts: NSF, NASA, DOE talk regularly about program planning, overlaps, issues
- Depending on science, project, contribution, and agency considerations, sometimes we partner on fabrication or provide facilities

Project Coordination & Oversight:

- Joint Oversight Group (JOG) : VERITAS, HAWC, LSST, DES, SuperCDMS-SNOLab
- Interagency Coordination Group (ICG): DESI, SPT-3G
- Finance Board meetings: Auger, FGST

Tri-Agency Group (TAG) – DOE, NASA, NSF-AST

Meeting monthly with US-leads on LSST, WFIRST, Euclid to discuss commonalities, coordination

International Efforts

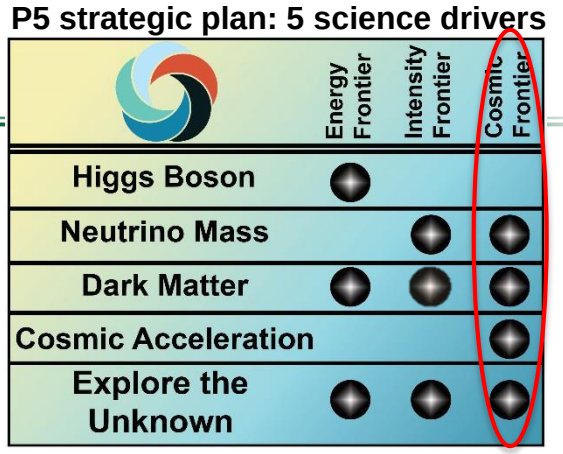
- DOE making country-level agreements to allow science partnerships to move forward.
- HEP participating on the Global Science Forum's Astro-particle Physics International Forum (APIF)

SUMMARY

- **An exciting time for HEP and the Cosmic Frontier!**
- **P5 developed compelling, realistic strategic plan with a consensus vision for US HEP**
- **→ HEP is moving forward to implement it.**

BACKUPS

May 2014 P5 Report – Cosmic Frontier Recommendations



P5 report recommendations addressed to the Cosmic Frontier ➔

- **Dark Energy**
  - Build DESI as a major step forward in dark energy science
  - Complete LSST as planned
- **Dark Matter**
  - Proceed immediately with a broad second-generation (G2) dark matter direct detection program with capabilities described in the text
    - 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 later in the decade.)**
- **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 later in the decade.)
- **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 – Major Item of Equipment (MIE) Projects

→*There are 4 MIE Projects – LSST, DESI, LZ, SuperCDMS-SNOLAB*

Large Synoptic Survey Telescope **(LSST) – Dark Energy Stage IV Imaging**

NSF project, HEP providing the LSSTcam (SLAC managing)

- LSSTcam & overall LSST Project going well; In CD-3 (full fabrication phase); Status review early Feb. 2016

Dark Energy Spectroscopic Instrument **(DESI) - Dark Energy Stage IV spectroscopic**

"HEP experiment" with LBNL managing: build DESI instrumentation & data management system, install & operate it on the Mayall telescope

- DESI project recently re-furbished the Mosaic camera on the Mayall, with LBNL providing the CCD's and Yale the mechanical parts and software. With NOAO, they installed "Mosaic-3" to use for z-band "MzLS" 2-year targeting survey for DESI; Also available for astronomers for other research; data being made public

HEP coordinating with NSF-AST to use ("lease") the Mayall telescope

- MOA for FY16-18 signed – HEP ramps up, NSF ramps down funds for Mayall operations for transition phase
- MOA for FY19+ being worked on – HEP providing full costs for Mayall for dark energy science operations

Current schedule:

- CD-3 review (ready for full fabrication phase) in May 2016
- Mayall shutdown, ready for DESI 1QFY18; DESI+Mayall commissioning complete & data-taking starts 1QFY20

LZ at Homestake Mine - WIMP dark matter search through dual phase liquid Xe – higher mass range

HEP leads, LBNL Project Office

→CD-1/3a approved April 2015; CD-2 "baseline" review being held in April 2016

SuperCDMS-SNOLAB - WIMP search using cryogenic solid-state crystals – lower mass range

HEP+NSF-PHY partnership, SLAC Project Office; CD-1 approval in Dec. 2015; CD-2 planned for FY17

Cosmic Frontier - R&D & Future planning

➔R&D towards P5 recommendations for the future:

Cosmic Frontier R&D – minimal funding expected for FY16 & FY17

Dark Matter (P5 recommended a DM-G3 R&D program)

- HEP concentrating on getting the DM-G2 experiments successfully started
- R&D in the next few years will support off-project studies for the DM-G2's, technologies for DM-G3; but NOT for DM-G3 concept design!
  - DM-G1 experiments completing in FY16 can apply for R&D funds for focused technology studies for the future

CMB-S4

- As recommended by P5, we are planning to do CMB-S4
- A small funding wedge in FY18 would put us in line with the P5 recommended project timeline
- Will work with NSF to develop possibilities

➔ Future Planning

"Cosmic Visions" groups: CMB, Dark Energy, Dark Matter (direct detection)

- HEP meetings with small HEP community groups monthly; info helps us to develop, guide and coordinate HEP plans and funding, as well as provide info to community and their efforts.

FY 2014-2017 HEP Program - Budget Status

	FY14	FY14	FY15	FY15	FY16	FY16	FY17
	PRB	Actual	PRB	Enacted	PRB	Enacted	PRB
Energy Frontier	154,687	152,386	153,639	147,584	154,555	150,723	150,998
Intensity Frontier	271,043	250,987	251,245	264,224	247,196	243,121	234,144
Cosmic Frontier	**99,080**	**96,927**	**101,245**	**106,870**	**119,325**	**130,582**	**130,069**
Theory & Comp. Phys	62,870	64,275	58,850	59,274	60,317	59,083	59,656
Advanced Tech R&D	122,453	150,270	114,242	120,254	115,369	115,494	118,285
Accelerator Stewardship	9,931	9,075	19,184	10,000	14,000	9,000	13,744
SBIR/STTR	21,457	0	20,595	20,794	21,138	20,897	22,580
HEP Subtotal	741,521	723,920	719,000	729,000	731,900	728,900	729,476
Construction, Line Item	35,000	51,000	25,000	37,000	56,100	66,100	88,521
HEP TOTAL	**776,521**	**774,920**	**744,000**	**766,000**	**788,000**	**795,000**	**817,997**
Office of Science TOT	5,152,752		5,111,155	5,067,738	5,339,794	5,350,200	5,672,069

*FY14 SBIR/STTR was ~ $21M, so FY2014 actual was ~ $796M.

Cosmic Frontier Budget History – details

May 2016

Cosmic Frontier ($K)		FY14 Actual	FY15 PRB	FY15 Actual	FY16 PRB	FY16 Enacted	FY16 Current (May 2016)	FY17 PBR
Research+Other	All	52,712	45,435	48,779	50,079	49,910	47,800	49,934
Research	All	52,712	45,435	48,779	50,079	46,195	47,265	46,991
Research	*Grants*	*13,157*	*11,422*	*11,773*	*12,565*	*11,595*	*12,703*	*11,607*
Research	*Labs*	*39,555*	*34,013*	*37,006*	*37,514*	*34,600*	*34,562*	*35,384*
Other Res						*3,715*	*535*	*2,943*
Exp Operations+Other		10,357	7,238	9,185	7,120	13,837	13,321	9,935
Exp Operations		10,357	7,238	9,185	7,120	9,190	9,574	8,925
Other Ops						*4,647*	*3,747*	*1,010*
Projects	All	30,660	41,000	46,403	58,701	66,835	67,695	70,200
Projects	***MIE***	**22,900**	**41,000**	**44,178**	**57,100**	**64,600**	**64,600**	**69,500**
Projects	*Undesig*					*500*		
Projects	*LSSTcamera*	*22,000*	*35,000*	*35,000*	*40,800*	*40,800*	*40,800*	*45,000*
Projects	*DM-G2*	*900*	*6,000*		*11,000*			
Projects	*LZ*			*3,050*		*10,500*	*10,500*	*10,500*
Projects	*SuperCDMS-SNOLAB*			*2,250*		*2,500*	*3,000*	*4,000*
Projects	*DESI*			*3,878*	*5,300*	*10,300*	*10,300*	*10,000*
Projects	***Small Proj Fab***			***1,025***	***1,601***	***2,035***	***2,035***	***0***
Projects	*All*				*1,601*			*0*
Projects	*ADMX-G2*			*925*		*935*	*935*	
Projects	*SPT-3G*			*100*		*1,100*	*1,100*	
Projects	***Future Proj R&D***	***7,760***	***0***	***1,200***	***0***	***200***	***1,060***	***700***
Projects	*R&D, general*					*200*		*700*
Projects	*Dark Matter*	*5,260*		*200*			*1,060*	
Projects	*SPT-3G*	*1,400*		*1,000*				
TOTAL	All	93,729	93,673	104,367	115,900	122,220	124,534	126,116
TOTAL+Other	All	93,729	93,673	104,367	115,900	130,582	128,816	130,069

TOTAL is the amount CF spends; "Other" includes extra funds for program reviews & direction, etc.

FY 2017 HEP Funding by Activity

HEP Funding Category ($ in K)	FY 2015 Current	FY 2016 Enacted	FY 2017 Request	Explanation of Changes (FY17 vs. FY16)
Research	334,225	327,389	331,123	Sustain support for research program
Facilities	264,634	254,979	252,037	Overall operations support reductions due to scheduled completion of projects
Projects	99,373	107,620	108,516	**Other Project Costs (OPC) includes CDR, project-specific R&D, prototyping and testing, installation and commissioning/pre-operations before CD-4*
Energy Frontier Projects	*15,000*	*19,000*	*18,967*	*Initial ATLAS/CMS upgrades complete in FY17; OPC* begins for HL-LHC detector upgrades*
Intensity Frontier Projects	*48,170*	*17,685*	*9,349*	*Reduction from ramp down of g-2 & end of LBNF/DUNE OPC*; SBN Program increases*
Cosmic Frontier Projects	*45,203*	*66,835*	*70,200*	*Planned ramp up supports fabrication of LSSTcam, DESI, SuperCDMS-SNOLab, LZ*
Other Projects	*1,000*	*4,100*	*10,000*	*Increase to support the FACET-II project*
Construction (Line Item)	37,000	84,115	103,741	Request engineering design, site preparation and long-lead procurement for the LBNF/DUNE; planned profile for Mu2e
SBIR/STTR	20,768*	20,897	22,580	
Total	**766,000***	**795,000**	**817,997**	

**** SBIR/STTR added to FY 2015 for comparison to FY 2016/2017***