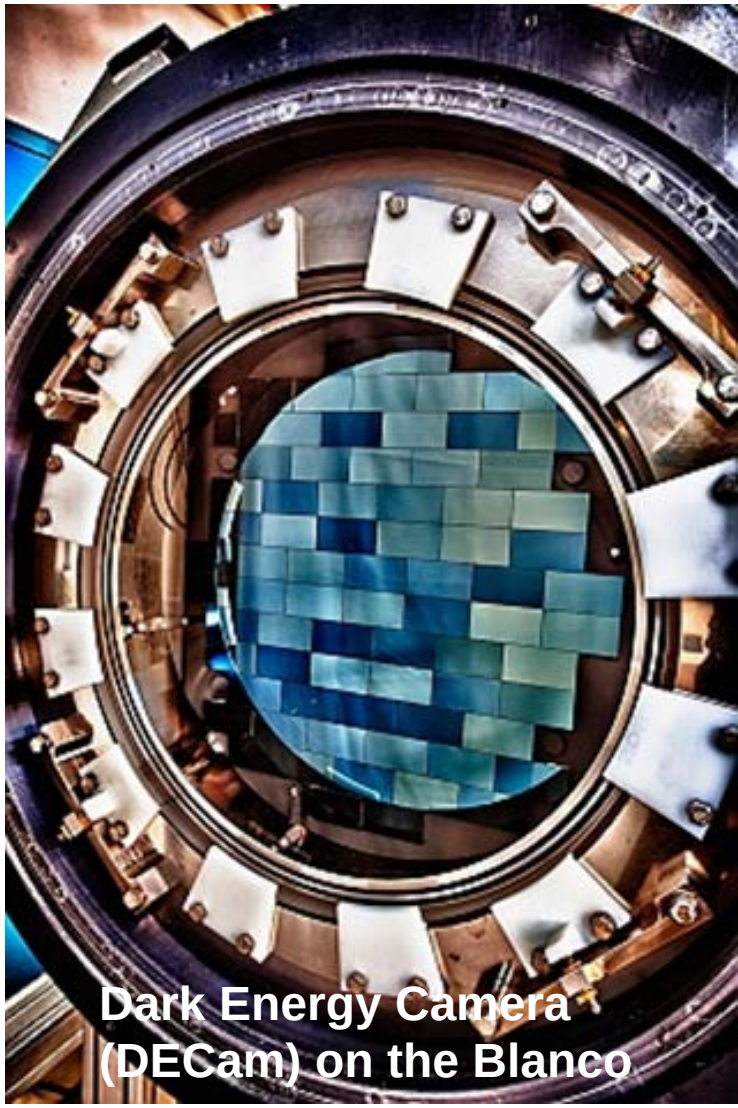
DOE High Energy Physics (HEP)

Update to the

NAS Committee on Astronomy & Astrophysics


Dark Energy Camera (DECam) on the Blanco

31 October 2016
Kathy Turner

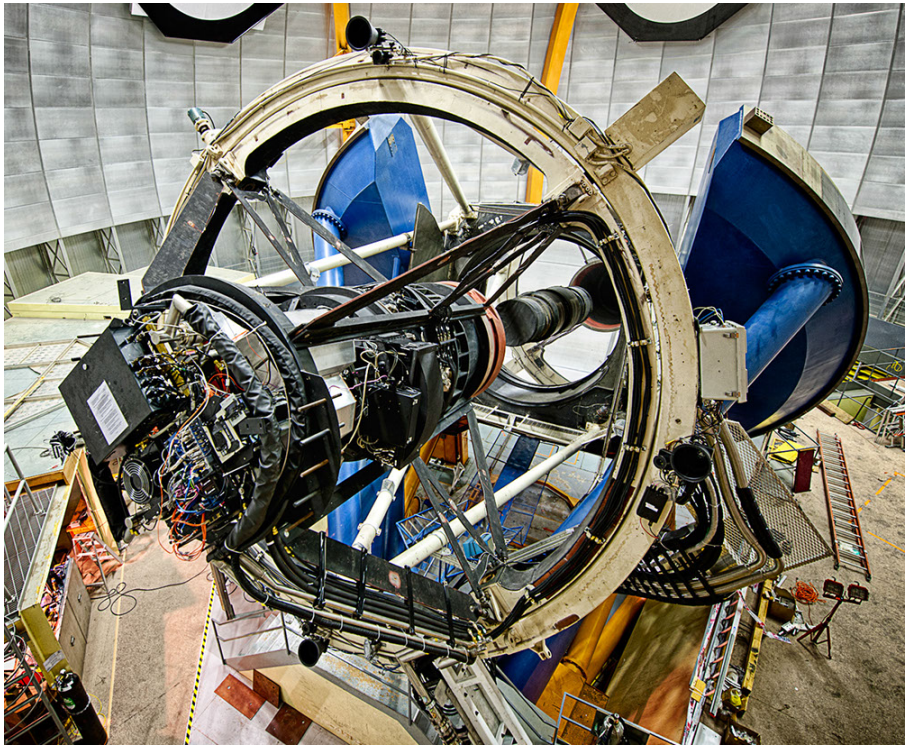
HEP Cosmic Frontier Program Managers:
Anwar Bhatti (IPA), Eric Linder (IPA), Michael Salamon, Kathy Turner

Outline

➔**Update to the Budget & Status - following the March 2016 briefing**

Outline:

- **HEP Budget, Strategy**
- **COSMIC FRONTIER status, budget**



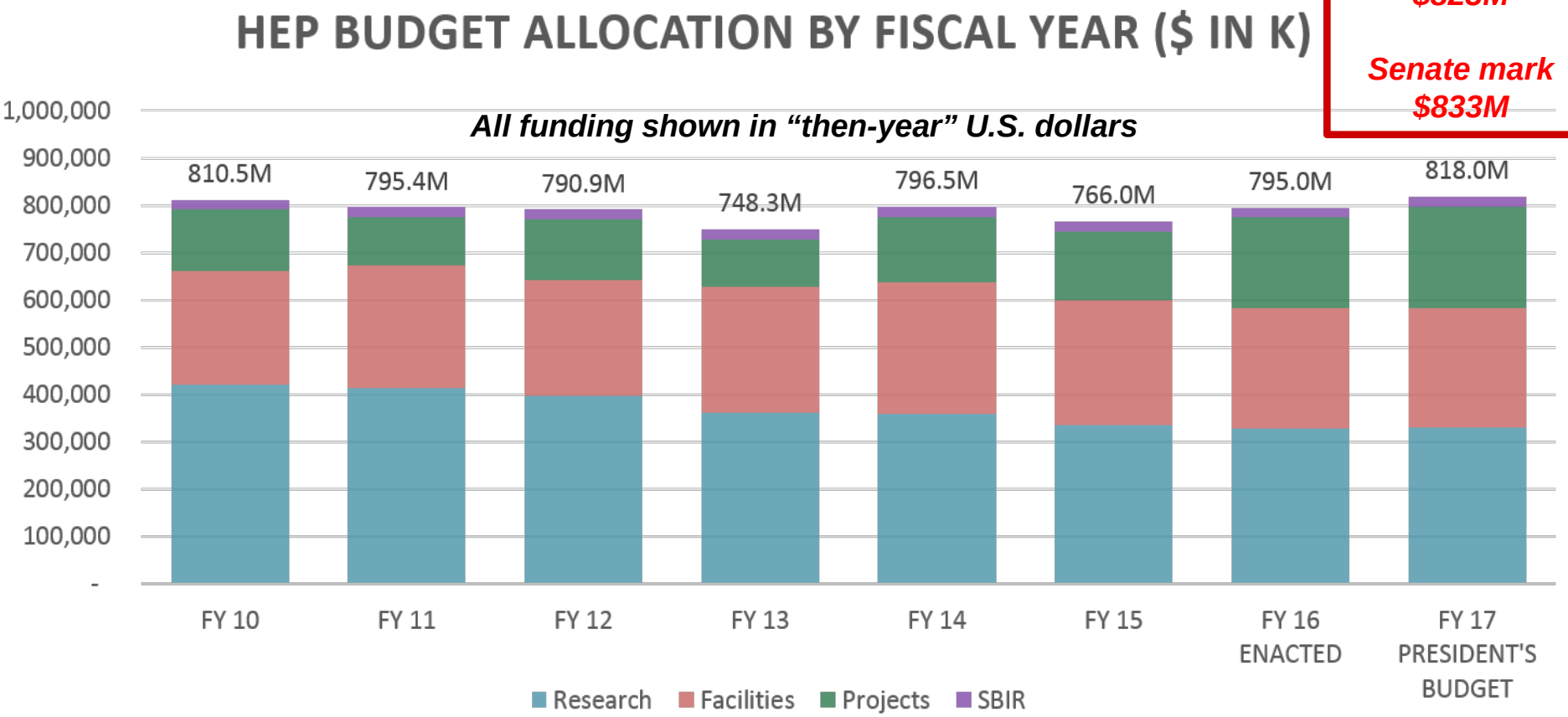
Dark Energy Camera (DECam) on the Blanco

HEP - Overall Budget Trend

- **Significant dip in FY13 from Congressional sequestration**
- **FY15 request developed prior to P5 Strategic Plan (May 2014) report release**
- **The enacted FY16 HEP Budget of $795M was above the Request & squarely in P5 Scenario B.**

House mark $823M

Senate mark $833M



→HEP must coordinate Projects, Facilities/Operations, and Research efforts to succeed in its mission
In recent years have traded Research for Project investments; Research expected to be ~flat in FY17.

FY 2017 HEP Budget Strategy

The FY17 President's Request for HEP ($818M) aims to continue the successful P5 implementation

The FY17 HEP budget request reflects the way that implementing the P5 strategy has evolved as the U.S. and international community has adopted and responded to it

- LHC (including upgrades) remains the highest-priority large project in the near-term
- LBNF/DUNE, the highest-priority large project in its time frame, has been reconfigured and is gaining international support much more rapidly than anticipated in the P5 strategy
- U.S. Administration and Congress strongly support establishing LBNF/DUNE as the first U.S.-hosted international science facility

This presents opportunity to advance the P5 strategy on shorter time scale through additional funding: "Scenario B+"

- HL-LHC accelerator and detector upgrades per CERN schedule
- Support all other projects in P5's Scenario B
- Maintain balance between Research, Operations, and Projects
- Additional funding *beyond* the above priorities would support accelerating the implementation of LBNF/DUNE

FY17 priorities include:

- Start the HL-LHC accelerator and detector projects
- Solidify international partnerships to establish LBNF/DUNE
- Complete existing projects, including suite of dark matter and dark energy experiments
- Maintain balance between research, facility operations, and projects

Cosmic Frontier Priorities: to advance leadership efforts in the dark matter, dark energy programs

- Fabrication ramp-up supports key P5 recommended projects: LSSTcam, DESI, SuperCDMS-SNOLab, LZ
- ADMX-G2 & SPT-3G are starting operating phase.
- Planning efforts for the future: CMB-S4, small R&D efforts on DM-G3

FY 2014-2017 HEP Program - Budget Status

HEP Budget History ($K)	FY14 PRB	FY14 Actual	FY15 PRB	FY15 Enacted	FY16 PRB	FY16 Enacted	FY17 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. Physics	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 TOTAL	5,152,752	5,066,372	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.
PRB = President's Request Budget

FY16: The enacted budget was above the Request and squarely in P5's Scenario B.
FY17: We are currently in a Continuing Resolution (CR) until Congress passes a budget → have to plan a budget to spend at last year's rate.

…Planning is difficult… We typically have plans for a full-year CR, the PRB and then the enacted budget.

Cosmic Frontier Program

Cosmic Frontier: Through ground-based telescopes, space missions, and deep underground detectors, research at the cosmic frontier aims to explore dark energy and dark matter, which together comprise approximately 95% of the universe.

Program Areas

- Study the nature of **Dark Energy**
- Direct Detection searches for **Dark Matter** particles
- **CMB –** Inflationary era, Neutrino properties
- **Cosmic-ray & Gamma-ray studi**es – particle properties, high energy acceleration mechanisms, indirect searches for dark matter particles
- **Other**: computational cosmology

+ related Theory, Detector development, computational, etc.

Cosmic Frontier: P5 Strategic Plan (May 2014) Recommendations

- **Dark Energy**
  - **Complete LSST** as planned
  - **Build DESI** as a major step forward in dark energy science
- **Dark Matter**
  - Proceed immediately with a broad second-generation (G2) dark matter direct detection program **(DM-G2)** 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 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 – Program Planning, P5 Implementation

Partners:

- Form partnerships or use other agency's facilities when needed → Significant planning & coordination with multiple offices in other agencies: NSF-PHY, NSF-AST, NSF-PLR, NASA
- International partners & contributions in most of our projects.

Plan Funding:

- Long-term support for our responsibilities in designing, building and operating projects
- **Support for HEP-style science collaboration in all stages, including coordinated data analysis to get the best possible science results**

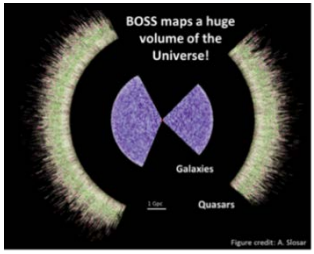
In FY17: Move Forward to Execute P5 Plan

- Plan successful completion of current operating experiments
- Move forward on near-term projects recommended by P5
  - Full steam ahead on fabrication of 4 Major Item of Equipment (MIE) Projects: **LSSTcam, DESI, LZ, SuperCDMS-SNOLAB**
  - 2 below-MIE projects completing fabrication & moving to operations phase: **SPT-3G, ADMX-G2**
  - Ramp-up on planning for Operations Phase
- Support for future projects later in P5 plan (e.g. CMB-S4, DM-G3) is extremely limited
  - Discussions with other agencies and community to determine possible future paths
- Ensure the science team is in place to adequately carry out the experiments & projects

Cosmic Frontier – Dark Energy

Precision measurements to differentiate between Cosmological Constant and new fields or modification to General Relativity

- staged, complementary suite of imaging, spectroscopy and supernova survey experiments



Operating/Completed:

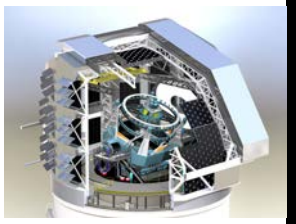
– ***BOSS* (spectroscopic)** ended in FY14; **eBOSS (spectroscopic)** started in FY15

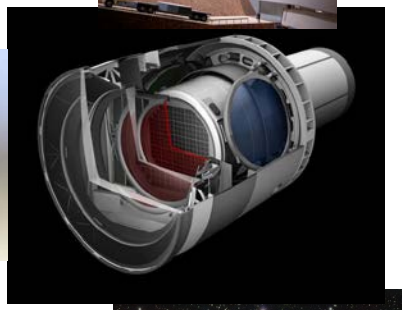
– ***DES* (imaging)** started 5-year survey in late FY13; HEP built the camera which operates on the Blanco telescope; partner w/NSF-AST

Design, Fabrication:

– ***Large Synoptic Survey Telescope* (LSST, Stage IV imaging)**

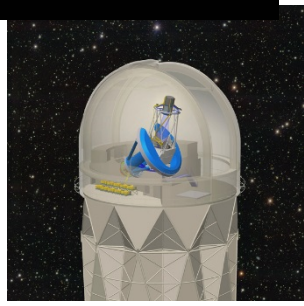
- HEP and NSF-AST (lead agency) partnership; HEP responsible for the LSST camera (SLAC)
- LSSTcam CD-3 (full fabrication approved) Aug. 2015
- LSST Project Status review Aug 2016; Commissioning phase review Jan. 2017
- LSST Facility Operations phase planning started; proposal in spring 2017
- LSST Dark Energy Science Collaboration (DESC) Ops review ~ March 2017





– ***Dark Energy Spectroscopic Instrument* (DESI, Stage IV spectroscopic)**

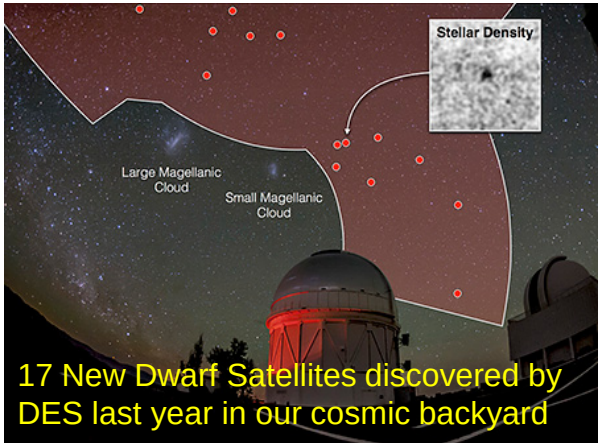
- "HEP experiment" with LBNL managing; CD-3 (full fabrication approved) June 2016
  - build DESI instrumentation & data management system for use on Mayall telescope with HEP providing partial support in FY16-18; full support starting in FY19
- DESI Operations phase planning started; Project and Operations plan reviews in summer 2017

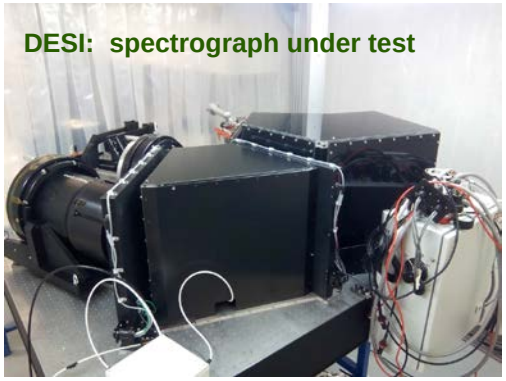


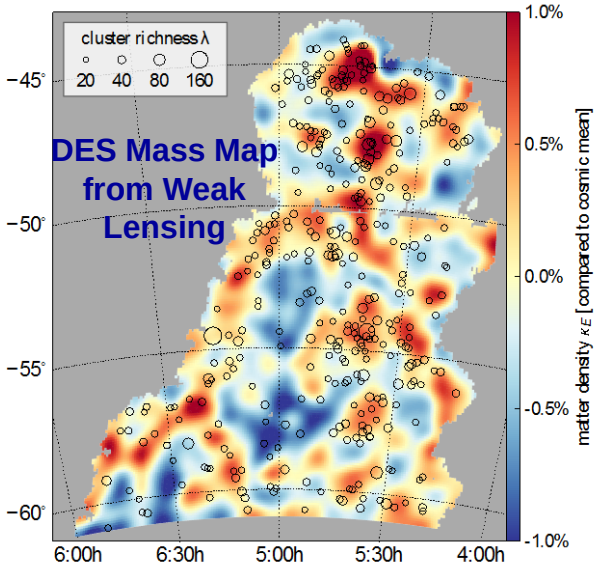
Research: In addition to above, HEP has research-only activities on **Euclid, WFIRST,** & **supernova surveys**

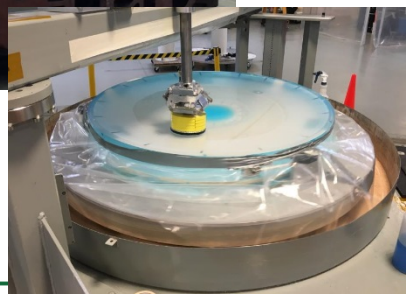
Understanding Dark Energy

A suite of imaging and spectroscopic surveys aim to address the question of what drives cosmic acceleration





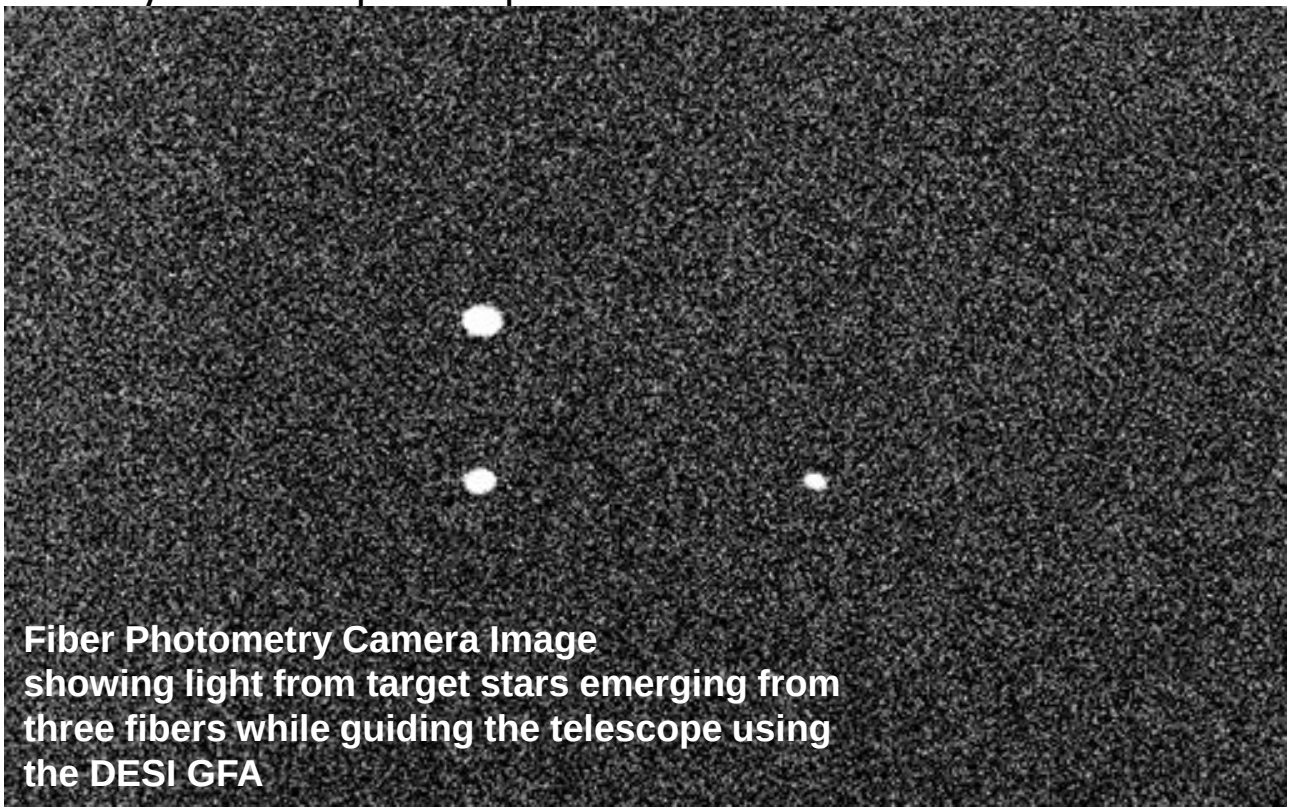




ProtoDESI a Success !!

Mid- September 2016: Completed, all goals accomplished!

"ProtoDESI completed its primary mission of demonstrating placing stars on fibers. We targeted three stars and all three were found. The image below is the record of the observed light from the three fibers. With this accomplishment we have demonstrated that we can guide the Mayall telescope into position and then move the fibers onto specific targets".



Fiber Photometry Camera Image showing light from target stars emerging from three fibers while guiding the telescope using the DESI GFA

Cosmic Frontier:
Direct Detection Dark Matter (DDDM)

→Learn the identity and nature of Dark Matter with staged program of experiments with multiple technologies & methods

Operating:
Completing Operations on current DM-Generation 1 (DM-G1) experiments in FY16/17: **ADMX-II, LUX, CDMS-Soudan, DarkSide-50, COUPP/PICO, DAMIC**

Design, Fabrication:
Progress continues on DM-G2's selected by HEP & NSF-PHY in July 2014

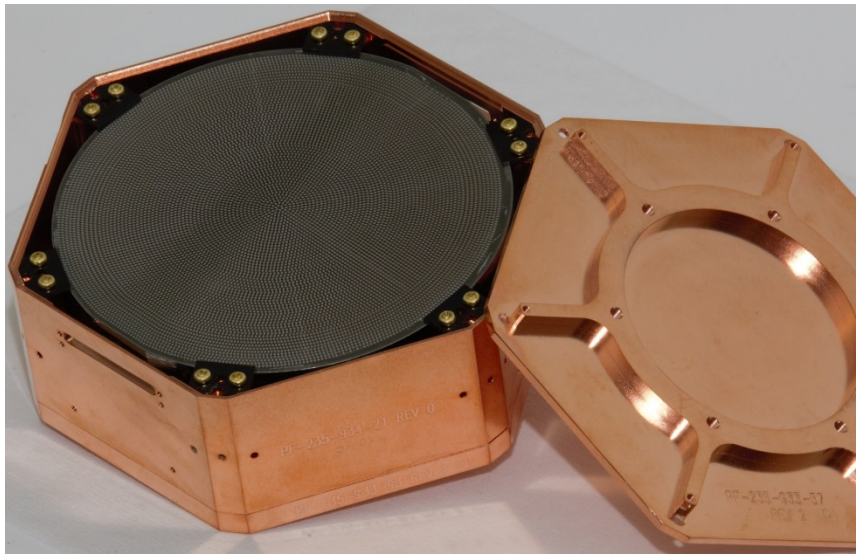
- **ADMX-G2** axion search at U.Wash. (HEP)
  - operations starting; status review Sept. 2016

- **LZ** at Homestake Mine in South Dakota (HEP, LBNL project office)
  - WIMP dark matter search through dual phase liquid Xe – higher mass range
  - Fabrication start (CD-1/3a) in FY15; CD-2/3a approval Aug. 2016

- **SuperCDMS-SNOLab** at Sudbury Neutrino Observatory in Canada
  - WIMP search using cryogenic solid-state crystals – lower mass range
  - HEP+NSF-PHY partnership, SLAC Project Office
    - CD-1 approval in Dec. 2015; Status review held July 2016

Cosmic Frontier:
Direct Detection Dark Matter (DDDM)

LZ: Large-scale prototype testing using liquid Xenon is underway at SLAC



SuperCDMS SNOLAB: first 100mm HV prototype detector

Flange sections for the LZ cryostat manufactured from ultra-low radioactivity Titanium

Cosmic Frontier: CMB

Gain insight into **inflationary epoch** at the beginning of the universe, **dark energy & neutrino properties** by studying oldest visible light.

Current Experiments:

- ***SPT-3G*** **– HEP provided support towards major upgrade of the camera to greatly increase sensitivity; Operations starting early 2017 (NSF-led)**

➔**CMB-S4 Community-based Collaboration brought together ground based community to plan future**

- **Notional array of several telescopes in Chile & South Pole with on the order of 0.5 M detectors**
- **Needs scale-up of detector fabrication, testing, and readout**

CMB-S4 Collaboration **Science Book:**
https://arxiv.org/abs/1610.02743

Future Planning:

As recommended by P5, HEP is planning to participate in a CMB Stage 4

- **HEP labs already heavily involved in R&D to align with P5**
- **HEP will coordinate efforts & roles within HEP program**

- **Working with NSF to coordinate planning and a path forward**
- **Have charged the AAAC to hold a CMB-S4 Concept Definition Taskforce (CDT)**
  - **Will be set up in the next few weeks**

Cosmic Frontier – Cosmic-ray, Gamma-ray

Use ground-based arrays, space telescopes, and an experiment on the International Space Station to perform indirect searches for dark matter, fundamental physics

→ **Significant inter-agency & international partnerships**

HEP Operations Roles Completing in FY16:

VERITAS *(w/NSF)*

– HEP operations support completed; finalizing HEP-supported analysis

Auger *(w/NSF-PHY)*

– HEP participation in operations & research ramping down in FY16; no participation planned on upgrade

Operations continuing:

Fermi/GLAST *(w/NASA)*

– HEP is supporting the Large Area Telescope Instrument Science Ops Center at SLAC; In coordination with NASA, HEP is planning to continue support of critical efforts at SLAC if operations go past 10 years

AMS *(w/NASA)*

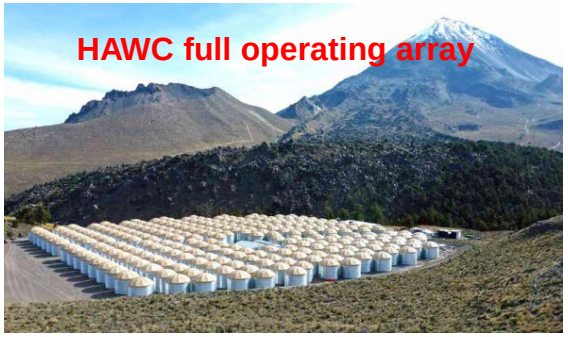
– operations continuing

HAWC *(w/NSF)*

– 5 year HEP-supported operations started early 2015

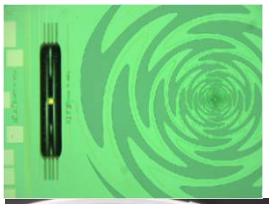

AMS on the International Space Station

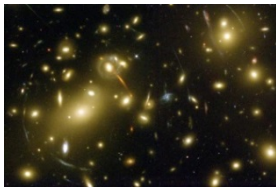

VERITAS in Sonoran desert Arizona

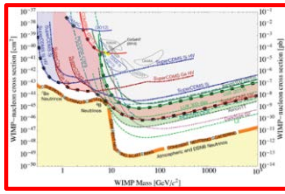

HAWC full operating array

Cosmic Visions (CV) Groups – looking towards the future

Following P5, HEP Labs & Community are redirecting programs to align with P5 priorities, including planning for the future.







HEP has started "Cosmic Visions (CV)" groups in several areas

- Allows interactions with small HEP community groups (~ monthly) as a 2-way line of communication for HEP-funded efforts.

NOTE: Of course, any HEP-funded R&D/technology plans need to be in the context of the larger non-HEP and global community

CV-CMB

Coordinate HEP technology R&D and other efforts for future CMB-S4 planning

CV-DE

Investigate future HEP directions following the end of construction of DESI and LSST; to complement, build on or extend these experiments in investigating the physics of dark energy.

CV-DM (Dark Matter Direct Detection)

Coordinate and investigate HEP technology R&D to optimize science from DM-G2 experiments and for future DM-G3 planning; Investigate other dark matter search avenues.

Cosmic Frontier Budget History – details

	FY14 Actual	FY15 PRB	FY15 Actual	FY16 PRB	FY16 Actual	FY17 PRB
Research	**52,712**	**45,435**	**48,779**	**50,079**	**47,326**	**46,991**
Grants	*13,157*	*11,422*	*11,773*	*12,565*	*12,705*	*11,607*
Labs	*39,555*	*34,013*	*37,006*	*37,514*	*34,621*	*35,384*
Exp Operations	**10,357**	**7,238**	**9,185**	**7,120**	**10,274**	**8,925**
Projects	**30,660**	**41,000**	**46,403**	**58,701**	**67,780**	**70,200**
Major Projects (MIE)	**22,900**	**41,000**	**44,178**	**57,100**	**64,600**	**69,500**
LSSTcamera	*22,000*	*35,000*	*35,000*	*40,800*	*40,800*	*45,000*
DM-G2	*900*	*6,000*		*11,000*		
LZ			*3,050*		*10,500*	*10,500*
SuperCDMS-SNOLAB			*2,250*		*3,000*	*4,000*
DESI			*3,878*	*5,300*	*10,300*	*10,000*
Small Project			***1,025***	***1,601***	***2,035***	***0***
All				*1,601*		*0*
ADMX-G2			*925*		*935*	
SPT-3G			*100*		*1,100*	
Future R&D	***7,760***	***0***	***1,200***	***0***	***1,145***	***700***
All						*700*
DESI (BigBOSS)	*1,100*					
Dark Matter	*5,260*		*200*		*1,145*	
SPT-3G	*1,400*		*1,000*			
TOTAL	**93,729**	**93,673**	**104,367**	**115,900**	**125,380**	**126,116**

Cosmic Frontier
Interagency & International Considerations & Activities

Interagency projects: can provide necessary or added resources provide opportunities to increase science.

- Depending on science, project, contribution, agency considerations it may make sense to partner, provide facilities, and/or coordinate efforts.
- While all government agencies follow the same rules, there are differences in the detailed agency and community practices which need to be taken into account to ensure data and science analysis return
  - Processes for planning/deciding on projects, managing/funding projects, funding research, etc
  - HEP emphasis on collaboration for coordinated science planning & analysis.

Interagency Coordination: NSF, NASA, DOE talk regularly about program planning, overlaps, issues

International: DOE making country-level agreements to allow science partnerships to move forward.

Cosmic Frontier ➔

Agency Coordination & Oversight: Joint Oversight Groups (JOG) and Agency Coordination Groups (ACG)

- International Finance Board for FGST w/NASA-AST, Auger
- DES, LSST: JOG with NSF-AST
- HAWC, SuperCDMS, VERITAS: JOG with NSF-PHY (also CONACYT for HAWC, NSF-AST for VERITAS Project)
- SPT-3G: JOG with NSF-PHY, NSF-AST & NSF-PLR
- DESI: ACG with NSF-AST

Other Groups:

- **Tri-Agency Group (TAG)** – DOE, NASA, NSF-AST meetings with LSST, WFIRST, Euclid US-leads to discuss commonalities, coordination, optimization of data, simulations, software
- **Astro-Particle International Forum (APIF)** – was led by Global Science Forum through 2016; GSF can no longer host and APIF recently accepted a proposal from KIPAC (SLAC/Stanford) to be the host going forward.

NAS Mid-Decadal Report (pre-publication draft Aug. 2016) → HEP Comments

FINDING 2-3: At the Department of Energy (DOE), support for astrophysics has been strong, and the budget reality has been close to the baseline plan presented in NWNH.
DOE-HEP Cosmic Frontier program following the NWNH and the P5 strategic plan is moving forward on the next phase of priority projects and experiments.

FINDING 3-1: LSST planning and construction have progressed well and are on schedule and within budget, successfully bringing together NSF funding, DOE funding, and private funding.
Agencies have worked hard to line up funding, activities and review schedules; planning for operations is ramping up now.

FINDING 3-2: Current projections for LSST performance and data products promise transformational scientific impact, as envisioned by NWNH. To realize the full scientific potential of this great new facility, funding that enables individual investigators and groups of investigators to deliver the scientific results will be critical.
HEP is supporting efforts on the LSST Dark Energy Science Collaboration to carry out planning, simulations and data challenges to be ready for precision dark energy studies when the data comes.

NAS Mid-Decadal Report (pre-publication draft Aug. 2016) → HEP Comments cont.

FINDING 3-4: Despite limited resources for MSIP, NSF-AST has funded an exciting set of highly ranked proposals in a heavily oversubscribed competition. Some mid-scale programs recommended by NWNH have also moved forward with funding from DOE and from the NSF Physics and Polar Programs. The scientific promise of these projects confirms the NWNH expectation that a mid-scale program would enable major advances that respond nimbly to opportunities on a diverse range of science topics.
DOE-HEP Cosmic Frontier program includes a suite of imaging and spectroscopic surveys moving from Stage 3 to 4; a suite of direct detection dark matter experiments using multiple technologies moving from Generation 1 to 2; small efforts in CMB moving towards planning for a CMB-S4.

p. 3.8 NWNH additionally recommended DOE and NSF funding of Theoretical and Computational Astrophysics Networks (TCAN)
- DOE HEP has a broad Theory program which supports a number of theory & computation cosmology efforts. We did not break out a piece of this to fund TCAN separately.

HEP Comments – Planning for the Next Astronomy & Astrophysics Decadal Survey

HEP's primary advice comes from HEPAP & we are following the P5 Strategic Plan (May 2014)

→For the next Decadal we are interested in science and opportunities to participate in projects that overlap with our program.

HEP uses the P5 Plan & P5 criteria to develop the program and determine which projects, and at what level, to invest in.

- Science goals and how it will address DOE-HEP goals
- Make unique, significant, coherent contributions to facilities/experiments selected for the program at a level commensurate with expected science return on HEP physics goals
    - Roles & responsibilities in line with our contributions/expertise
    - **What does HEP community bring to the table?**
        - » Need to bring unique, visible, leadership contributions, especially if it's an area usually supported by another agency. Typically this is expertise in developing & delivering state-of-the art instrumentation, lab infrastructure & project management, "big data" computing facilities and expertise, and having a cohesive science collaboration to carry out all phases of the project/experiment and deliver precision results.
- For facilities with broader science program (e.g. astronomy facilities) than interests of the HEP program, make project contributions at appropriate level & support research efforts for our science interests
- Balance & Stages: Staged implementation, results; varying project size; complementary and varying methods/technologies; balance between science areas and speculative/guaranteed results

Summary

P5 developed compelling, realistic strategic plan with a community consensus vision
→The HEP FY2016 Budget & FY 2017 Budget Request continues the implementation of the P5 global vision for particle physics

- Close coordination with the other agencies; significant partnerships.
- Building further international cooperation and partnerships was an important theme of the P5 Strategic Plan.

Cosmic Frontier Program – Exciting Time!

- **4 MIE Projects in Fabrication Phase**
- **2 small Projects Fabrication → Operations**
- **Working with other agencies & projects to plan for Experiment & Science Operations**

Future Planning:

- **Cosmic Visions Groups**
- **DOE & NSF are Charging the AAAC to carry out a CMB-S4 Concept Definition Taskforce**