



High Energy Physics (HEP) Program Status Update to the AAAC Meeting

June 1, 2015

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HEP PROGRAM – PRIORITIES & BUDGET



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HEP Program: FY 2015 → 2016 Priorities

- HEP is implementing the strategy detailed in the May 2014 report of the Particle Physics Project Prioritization Panel (P5), formulated in the context of a global vision for the field
 - Highest priority major projects are Large Hadron Collider (LHC) detector (ATLAS, CMS) upgrades in the near-term and Long Baseline Neutrino Facility (LBNF; aka LBNE) in the mid-term; Near term Cosmic Frontier projects are ready to go
 - LBNF will be the first truly international [ground-based] experiment hosted by the US
- Energy Frontier: Continue LHC program with higher collision energy (13+ TeV)
- Intensity Frontier: Develop a world-class U.S.-hosted Long Baseline Neutrino Facility (LBNf)
- Cosmic Frontier: Advance our understanding of dark matter and dark energy
 - Development of new capabilities in dark matter detection and dark energy exploration continues
 - Lay the ground work for future projects
- Accelerator Stewardship
 - broader applications of accelerator technologies
- Construction/Major Items of Equipment (MIEs) support reflects P5 priorities:
 - The Long Baseline Neutrino Facility (LBNF) continues its design phase as the project baseline cost and technical scope are revised while incorporating international in-kind contributions
 - The LHC ATLAS and CMS Detector Upgrade projects continue fabrication
 - Muon g-2 continues accelerator modifications and fabrication of the beamline and detectors
 - LSSTcam fabrication support increases according to planned profile (fabrication started FY14)
 - Fabrication proceeds on the Dark Energy Spectroscopic Instrument (DESI)
 - Fabrication proceeds on the dark matter experiment MIEs: SuperCDMS-SNOlab and LZ
 - Construction continues for the Muon to Electron Conversion Experiment (Mu2e)

HEP Program: FY 2015 → FY 2016 Budget

FY15:

The **enacted FY15 Budget** for HEP is \$766M, between P5's scenario A&B.

Cosmic Frontier Major Item of Equipment (MIE) projects (LZ, SuperCDMS-SNOLab, DESI).

➔ **These were all approved as new project starts.**

The actual schedule for starting fabrication depends on each project's schedule, etc.

Note: SPT-3G and ADMX-G2 are also starting but are below the MIE project cutoff, so not called out directly in the budget documents.

FY16:

The **FY16 President's Request** for HEP is up relative to FY15:

+ \$44M over FY15 Request

+ \$22M over FY15 Enacted

It is ~ \$11.5M above the **FY14 Request** (\$776M). If the Request is passed, this would be slightly above the P5 scenario B, which was flat-flat for 3 years starting with the FY14 Request and then increasing 3% per year.

May 2015:

FY16 House Mark: \$776M

FY16 Senate Mark: \$788.1M

FY 2016 High Energy Physics Budget Status

HEP Budget History (\$K)

| | FY 2014 | FY 2014 | FY 2015 | FY 2015 | FY 2016 | FY 2016 | FY 2016 |
|-------------------------------|----------------|----------------|----------------|----------------|----------------|-----------------------|-------------------------|
| | Request | Actual | Request | Enacted | Request | House Mark (~ 5/6/15) | Senate Mark (~ 5/27/15) |
| Energy Frontier | 154,687 | 152,386 | 153,639 | 147,584 | 154,555 | | |
| Intensity Frontier | 271,043 | 250,987 | 251,245 | 264,224 | 247,196 | | |
| Cosmic Frontier | 99,080 | 96,927 | 101,245 | 106,870 | 119,325 | | |
| Theoretical and Computational | 62,870 | 64,275 | 58,850 | 59,274 | 60,317 | | |
| Advanced Technology R&D | 122,453 | 150,270 | 114,242 | 120,254 | 115,369 | | |
| Accelerator Stewardship | 9,931 | 9,075 | 19,184 | 10,000 | 14,000 | | |
| Construction | 35,000 | 51,000 | 25,000 | 37,000 | 56,100 | | |
| Total | 755,064 | 774,920 | 723,405 | 745,206 | 766,862 | | |
| SBIR/STTR* | 21,457 | 0 | 20,595 | 20,794 | 21,138 | | |
| HEP Total | 776,521 | 774,920 | 744,000 | 766,000 | 788,000 | 776,000 | 788,100 |
| Office of Science Total | 5,152,700 | | 5,111,155 | 5,067,738 | 5,339,800 | 5,100,000 | 5,143,900 |

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



COSMIC FRONTIER PROGRAM STATUS



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HEP Cosmic Frontier Research Thrusts

Dark Energy

- **Determine the nature of Dark Energy using precision measurements to differentiate between Cosmological Constant, new fields or GR modification**
 - Operating complementary suite of imaging, spectroscopy and supernova surveys: BOSS (completed FY14), DES (5 yr survey started end-FY13)
 - In FY15, Final Design for DESI (spectroscopic) and Fabrication underway for LSST (imaging) in FY15 → next generation “Stage-IV” suite of experiments underway

Dark Matter

- **Learn the identity and nature of Dark Matter**
 - Suite of 1st Generation (G1) experiments operating with multiple techniques
 - Portfolio 2nd Generation (G2) experiments approved & moving to fabrication phase → ADMX-G2, LZ, SuperCDMS-SNOLAB

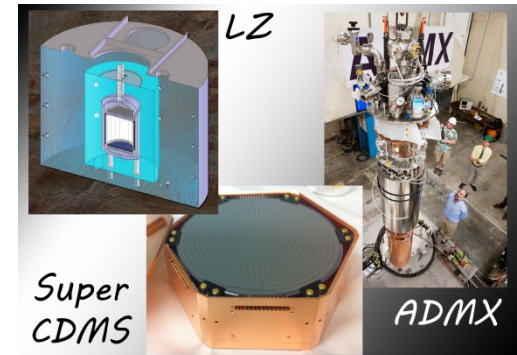
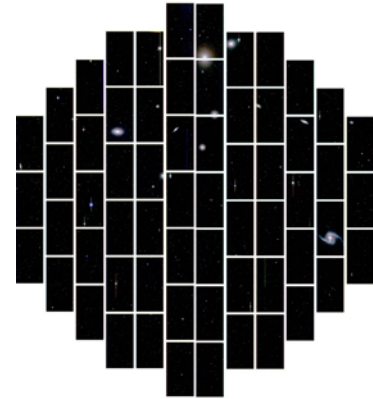
Cosmic-ray, Gamma-ray

- **Explore high energy particle acceleration mechanisms and perform indirect searches for dark matter candidates**
 - Operating ground-based arrays (Auger, VERITAS, HAWC started FY15), space missions (Fermi/GLAST) & AMS-02 experiment on International Space Station

Cosmic Microwave Background

- **Gain insight into inflationary epoch at the beginning of the universe, dark energy, and neutrino properties by understanding the oldest visible light**
 - Currently operating South Pole Telescope (SPT) polarization experiment and SPT-3G upgrade underway (FY15 fabrication start for HEP)
 - Community planning for future experiments underway including CMB-S4.

Dark Energy Survey First Light
Sep 2012




P5: Cosmic Frontier Strategy

P5 report recommendations addressed several thrust areas of 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
- **Cosmic Microwave Background (CMB)**
 - Support CMB experiments as part of the core particle physics program
 - The multidisciplinary nature of the science warrants continued multiagency support
- **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.

P5 strategic plan: 5 science drivers

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



Cosmic Frontier Budget History

HEP Budget History (\$K)

| | FY 2014 | FY 2015 | FY 2015 | FY 2015 | FY 2016 |
|---|---------------|----------------|----------------|-------------------------------------|----------------|
| | | | | Current (May 2015 "snapshot") | |
| | Actual | Request | Enacted | | Request |
| Research | 52,712 | 45,435 | 47,735 | 48,934 | 50,079 |
| <i>Grants</i> | <i>13,157</i> | <i>11,422</i> | <i>11,659</i> | <i>12,033</i> | <i>12,565</i> |
| <i>National Laboratories</i> | <i>39,555</i> | <i>34,013</i> | <i>36,076</i> | <i>36,901</i> | <i>37,514</i> |
| Facility Operations and Experimental Support | 10,357 | 7,238 | 8,790 | 9,135 | 7,120 |
| Projects | 30,705 | 41,000 | 44,203 | 45,478 | 58,701 |
| MIE | <i>22,900</i> | <i>41,000</i> | <i>41,878</i> | <i>43,428</i> | <i>57,100</i> |
| LSST camera (FY14 fab start) | <i>22,000</i> | <i>35,000</i> | <i>35,000</i> | <i>35,000</i> | <i>40,800</i> |
| DM-G2: LZ & SuperCDMS-SNOLab (FY15 MIE approved) | <i>900</i> | <i>6,000</i> | <i>4,800</i> | | <i>11,000</i> |
| LZ (FY15 MIE approved) | | | | <i>2,000</i> | |
| SuperCDMS-SNOLAB (FY15 MIE approved) | | | | <i>2,800</i> | |
| DESI (FY15 MIE approved) | | | <i>2,078</i> | <i>3,628</i> | <i>5,300</i> |
| Small Project Fabrication, FY15: SPT-3G, ADMX-G2 | | | <i>2,225</i> | <i>1,025</i> | <i>1,601</i> |
| Future Project R&D, FY15: SPT-3G, ADMX-G2 | <i>7,760</i> | | <i>100</i> | <i>1,025</i> | |
| TOTAL | 93,729 | 93,673 | 100,728 | 103,547 | 115,900 |
| Other Costs | 3,198 | 7,572 | 4,817 | 5,794 | 3,425 |
| Total – Cosmic | 96,927 | 101,245 | 105,545 | 109,341 | 119,325 |



Cosmic Frontier Status – Dark Energy

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

– Operating & planning complementary suite of imaging, spectroscopy and supernova survey experiments

- **Operating:**

- *BOSS* (spectroscopic) ended in FY14
- *DES* (imaging) started FY13
- SN surveys continue



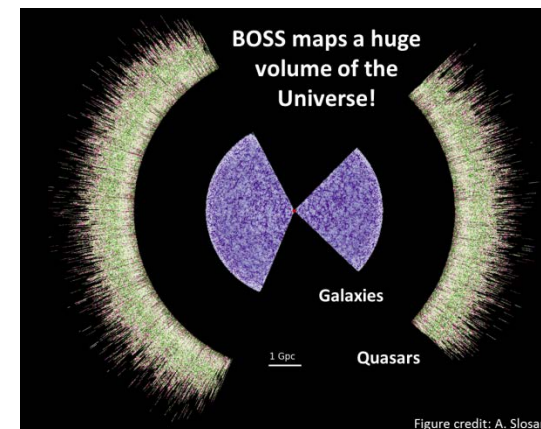
Baryon Oscillation Spectroscopic Survey (BOSS)

Stage 3 Dark Energy experiment - spectroscopic survey

- Galaxy clustering redshift survey including Baryon Acoustic Oscillation (BAO) distance and Redshift Space Distortion (RSD) growth methods.
- Mapping 3-D positions of 1.5 million galaxies & line-of-sight to 160,000 quasars using Lyman-alpha forest.
- BOSS was the flagship survey on the Sloan Digital Sky Survey (SDSS) Phase III at Apache Point Observatory in New Mexico; DOE funded the SDSS spectrograph upgrade needed for BOSS and also BOSS operations.

Partnership: DOE, NSF, the Sloan Foundation, and private and foreign institutional contributions

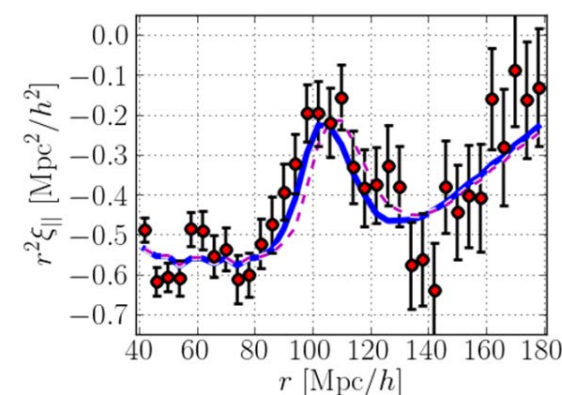
Collaboration: ~160 scientists from ~15 US institutions and UK, Brazil, Germany, France, Japan



Recent Highlights: (May 2015)

- 5-year survey of 10,000 sq deg was completed in July 2014
- Final data set (DR12) released in January 2015, <http://www.sdss.org>
- Final science papers expected mid2015, including dark energy parameters, neutrino mass constraints, Lyman-alpha $z \sim 2-3$ expansion rate

→ E.O. Lawrence Award to PI David Schlegel, May 2015



Cosmic Frontier Highlight:

DES Discovers Dwarf Galaxies, FGST Constrains Dark Matter

Stage-III dark energy experiment - imaging survey

4 techniques: galaxy angular clustering (300 million galaxies), weak lensing tomography, galaxy cluster counts (10000s), supernova distances (3500).

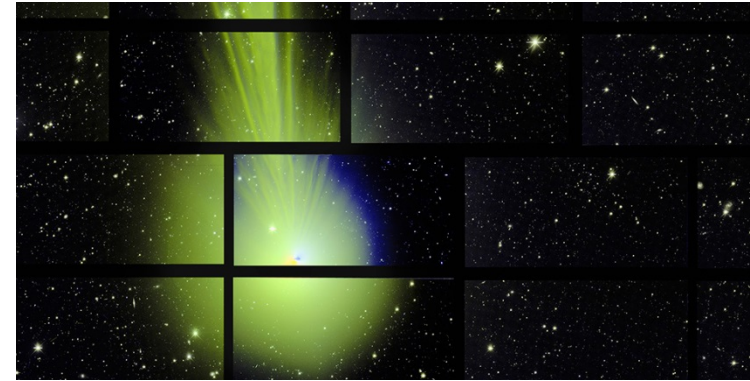
HEP supported fabrication of Dark Energy camera (DECam), managed by Fermilab, now installed on Blanco telescope at CTIO (Chile), and supporting survey operations

- NSF supporting telescope operations and data management
- 525 nights over 2013-2017

Partnership: DOE/NSF partnership + private & foreign contributions; JOG meets monthly.

Collaboration: 4 DOE labs (FNAL lead, ANL, SLAC, LBNL), NOAO/CTIO, NCSA, 20 universities from US, Spain, UK, Brazil, Germany, Switzerland.

- Images from the Dark Energy Survey's 570-megapixel camera moves science forward as they continue to make headlines
- DES data has led to the discovery of 9 new dwarf satellite galaxies orbiting the Milky Way (**April 2015 APS meeting**)
 - 139 deg² weak lensing mass map, largest ever
 - Dwarf satellite galaxies are dominated by dark matter and present an excellent cosmic laboratory to search for signs of dark matter annihilation
 - Fermi Gamma-ray Space Telescope used the newly discovered dwarf galaxies to put a tight limit on dark matter annihilation cross-section
 - DES may find as many as 30 dwarf galaxies in the region of the sky it scans
 - 4 papers out in March 2015 using these data – from DES and FGST collaborations and independent work



*DES image of
dwarf galaxy candidate*



*Dwarf galaxy candidate with
other matter blacked out*

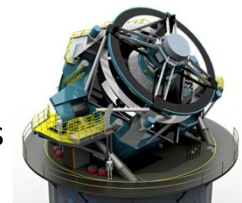


Cosmic Frontier Status – Dark Energy

Design, Fabrication:

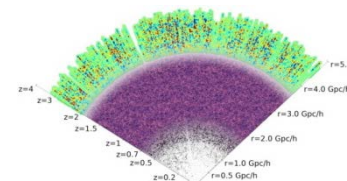
– **Large Synoptic Survey Telescope (LSST, Stage IV imaging)**

- Partnership with NSF-Astronomy (DOE+NSF MOU), with international, private contributions
- NSF is the lead – telescope facility and Data Management
- DOE building the LSST-camera - Approved as an MIE (Major Item of Equipment) project in FY14;
- CD-2 “baseline” approved Jan 2015; CD-3 review in August 2015
- LSST Dark Energy Science Collaboration (DESC) – planning, studies continue to deliver science requirements to DOE
- Weekly DOE/NSF Joint Oversight Group (JOG) meetings



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

- Approved as an MIE project in FY15
- CD-1 approved March 2015; CD-2 “baseline” review scheduled for July 2015
- Finalizing MOA with NSF to start supporting NOAO operations costs in FY16, ramping up to full support for dark energy survey operations in FY2019
- Bi-weekly DOE/NSF Joint Oversight Group (JOG) meetings



• **Future planning**

- Community starting to investigate other experiments/project to complement the LSST era (recent National Academy of Science Optical & Infrared study)
- HEP will start discussions with our community to coordinate R&D efforts, planning for future projects and how best to extract precision measurements in the coming year.



Direct Detection Dark Matter (DDDM)

Learn the identity and nature of Dark Matter:

Staged program of experiments w/multiple technologies

LUX



- **Operating:**
 - 1st generation (DM-G1) experiments:
 - ADMX, LUX, CDMS-Soudan, DarkSide, COUPP/PICO
- **Design, Fabrication:**
 - DOE and NSF-Physics announced in July 2014 selection of Dark Matter Generation 2 (DM-G2) experiments to move forward to fabrication phase:
 - ADMX-G2 is a small project (below MIE) and started at the end of FY14.
 - LZ had successful CD-1 review in March 2015; approved as MIE in FY15
 - SuperCDMS-SNOLab CD-1 review planned for September 2015; approved as MIE in FY15
 - P5: The overall DOE & NSF coordinated DDDM program will need to include DM-G2 project(s), operations of current experiments, background and material studies, and future R&D efforts
 - HEP now concentrating on getting the DM-G2 experiment(s) successfully started.
 - FY15/16 – small amount of R&D funding planned; significant R&D or DM-G3 studies assumes adequate funding and will take place later on
- **Future planning**
 - HEP will start discussions with our community to coordinate R&D efforts and needs as well as planning for future in the coming year.



Cosmic Frontier Status – Cosmic-ray, Gamma-ray

Explore particle acceleration mechanisms and perform indirect searches for dark matter candidates

– Using ground-based arrays, space telescopes, and AMS on the International Space Station

- **Operating:**

- *Fermi/GLAST*

- *HEP participation planning in coordination with NASA*

- *VERITAS*

- *HEP participation ramping down*

- *Auger*

- *HEP ramping down; no participation planned on upgrade*

- *AMS*

- *operations continuing*

- *HAWC*

- *5 year operations started early 2015*

- **Future Planning: Cherenkov Telescope Array (CTA)**

- US Community planning participation in a European-led next generation gamma ray observatory

- HEP response to P5 recommendation, funding availability & programmatic priorities:

- HEP not continuing support of research, planning, R&D efforts on CTA.



AMS on the International Space Station



HAWC full operating array (Jan 2015)



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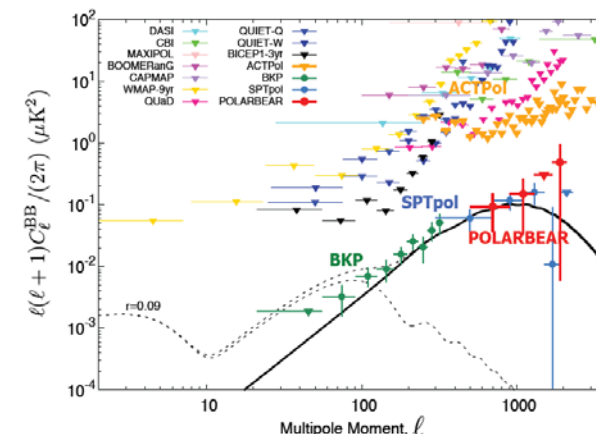
Cosmic Frontier Status – CMB

Gain insight into **inflationary epoch** at the beginning of the universe, **dark energy**, and **neutrino properties** by studying the oldest visible light.
B mode power spectrum starting to be mapped

- **Operating:**
 - *South Pole Telescope polarization (SPTpol)* where HEP provided support for outer-ring detectors
 - Also participation in Planck (through NERSC); research activities on BICEP2, POLARBEAR
- **Fabrication:**
 - *SPT-3G*
 - major upgrade of the camera to greatly increase sensitivity; HEP funding R&D and fabrication phase (FY14-16)
- **Future Planning:**
 - Community planning for a CMB Stage IV experiment
 - HEP has started meeting with our labs to oversee coordination of efforts within the HEP program and plan for technical, science studies
- **High Performance Computing**
 - NERSC used for analysis of many CMB experiments: in 2014 ~ 10 experiments with ~ 100 users at a time, with ~ 10M CPU-hours
 - HEP MOU with NASA for Planck analysis at NERSC; in 2014, 100M CPU-hours, NERSC Achievement Award for High-Impact Science



South Pole Telescope (SPT)



Interagency Activities, etc.

Cosmic Frontier:

Projects

Joint Oversight Group (JOG) meetings:

VERITAS, HAWC, DESI, LSST, DES, SuperCDMS-SNOLab

Finance Board meetings: Auger, FGST

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

Started meeting monthly with US-leads on LSST, WFIRST, Euclid to discuss commonalities, coordination of data, simulations (1 meeting so far and another scheduled)

Cosmic Frontier - Overall

- HEP participating in NAS Mid-Decade review

Data Plans

- Have asked each Project/Experiment for a summary-level Data Plan by end June
 - Use for referencing in research proposals; also to check against Principles for Access in Astrophysics

HEP overall

- Country-level agreements being made with other country partners to allow science partnerships to move forward.

- ~~Interagency~~ DOE-HEP/NSF-PHY meetings to discuss program.

HEP PROGRAM - 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.

Close coordination with the other agencies.

Looking forward to participation in mid-decade review to get input on Cosmic Frontier opportunities



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