U.S. DEPARTMENT OF ENERGY | Office of Science

# Office of High Energy Physics (HEP) Program Update

*AAAC meeting*

*June 27, 2018*

*Kathy Turner - Program Manager, Cosmic Frontier*

*Office of High Energy Physics*

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

- HEP program intro
- Strategy, Guidance
- Budget
- Portfolio Review
- QIS
- Computing planning
- PI meeting
- Cosmic Frontier – status & planning

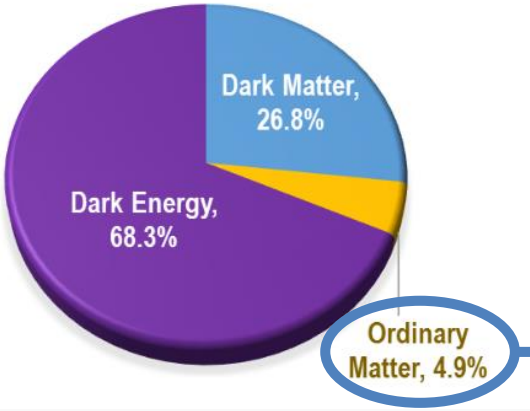
# HEP program intro

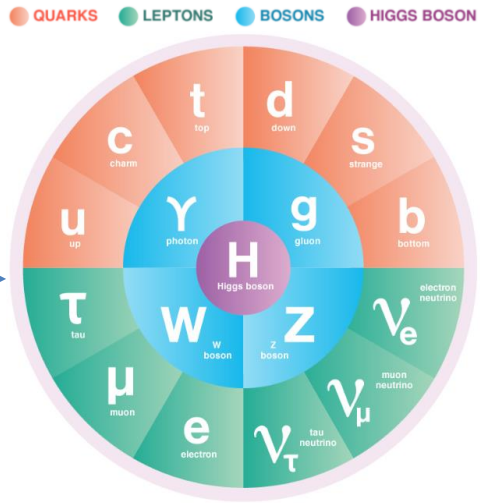
# The High Energy Physics Program Mission

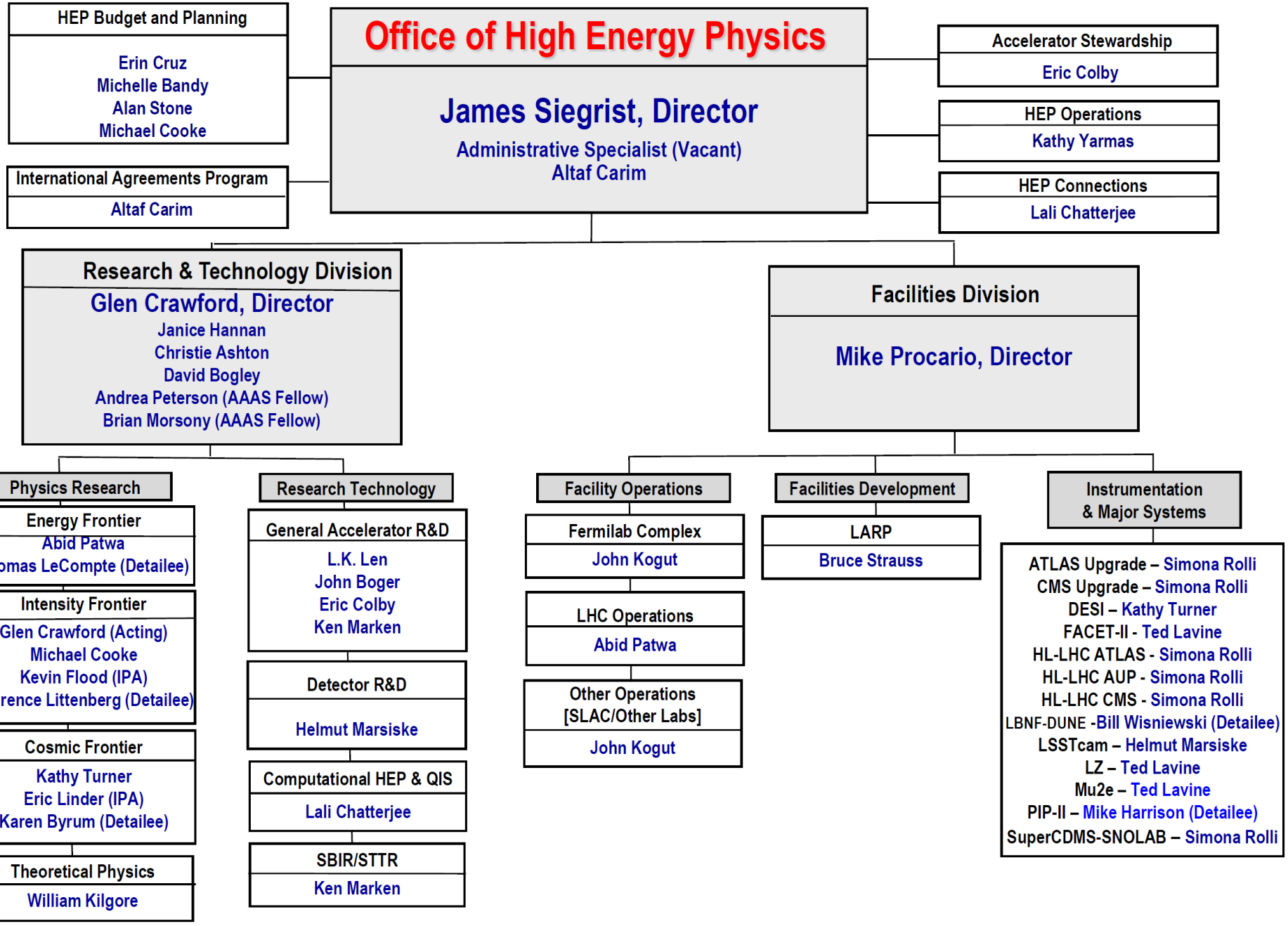
… is to understand how the universe works at its most fundamental level:

- Discover the elementary constituents of matter and energy
- Probe the interactions between them
- Explore the basic nature of space and time

- The DOE Office of High Energy Physics fulfills its mission by:
  - Building **projects** that enable discovery science
  - Operating **facilities** that provide the capability for discoveries
  - Supporting a **research** program that produces discovery science





HEP Budget and Planning
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Glen Crawford, Director
Janice Hannan
Christie Ashton
David Bogley
Andrea Peterson (AAAS Fellow)
Brian Morsony (AAAS Fellow)
Facilities Division
Mike Procario, Director
Physics Research
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Abid Patwa
Thomas LeCompte (Detailee)
Intensity Frontier
Glen Crawford (Acting)
Michael Cooke
Kevin Flood (IPA)
Laurence Littenberg (Detailee)
Cosmic Frontier
Kathy Turner
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Karen Byrum (Detailee)
Theoretical Physics
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Detector R&D
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Fermilab Complex
John Kogut
LHC Operations
Abid Patwa
Other Operations
[SLAC/Other Labs]
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LARP
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Instrumentation
& Major Systems
ATLAS Upgrade – Simona Rolli
CMS Upgrade – Simona Rolli
DESI – Kathy Turner
FACET-II - Ted Lavine
HL-LHC ATLAS - Simona Rolli
HL-LHC AUP - Simona Rolli
HL-LHC CMS - Simona Rolli
LBNF-DUNE -Bill Wisniewski (Detailee)
LSSTcam – Helmut Marsiske
LZ – Ted Lavine
Mu2e – Ted Lavine
PIP-II – Mike Harrison (Detailee)
SuperCDMS-SNOLAB – Simona Rolli

# Strategy, Guidance

# Program Advice and Coordination

- Formal advice (Federal Advisory Committee Act)
  - High Energy Physics Advisory Panel (HEPAP)
    - Jointly serves DOE and National Science Foundation (NSF)
    - **2014: P5 long-term strategy report (our strategic plan)**
    - 2015: Accelerator R&D Subpanel report
  - Astronomy and Astrophysics Advisory Committee (AAAC)
    - Advises DOE, NSF, and NASA on selected issues of mutual interest within the fields of astronomy and astrophysics (*e.g. CMB-S4 Conceptual Design Taskforce*)
- Community input
  - National Academies of Science: Astronomy and Astrophysics Decadal Survey (*New Worlds, New Horizons*)
  - DOE Workshop reports, including Quantum Sensors, Accelerator R&D Roadmaps, Technology Connections, Cosmic Visions Dark Matter, Cosmic Visions Dark Energy, Basic Research Needs, etc.
- International & Interagency coordination



# The Science Drivers of Particle Physics

The U.S. long-term strategy report identified five **intertwined science drivers**, compelling lines of inquiry that show great promise for discovery:

- Use the **Higgs boson** as a new tool for discovery *2013
- Pursue the physics associated with **neutrino mass** *2015
- Identify the new physics of **dark matter**
- Understand **cosmic acceleration**: dark energy and inflation *2011
- **Explore the unknown**: new particles, interactions, and physical principles

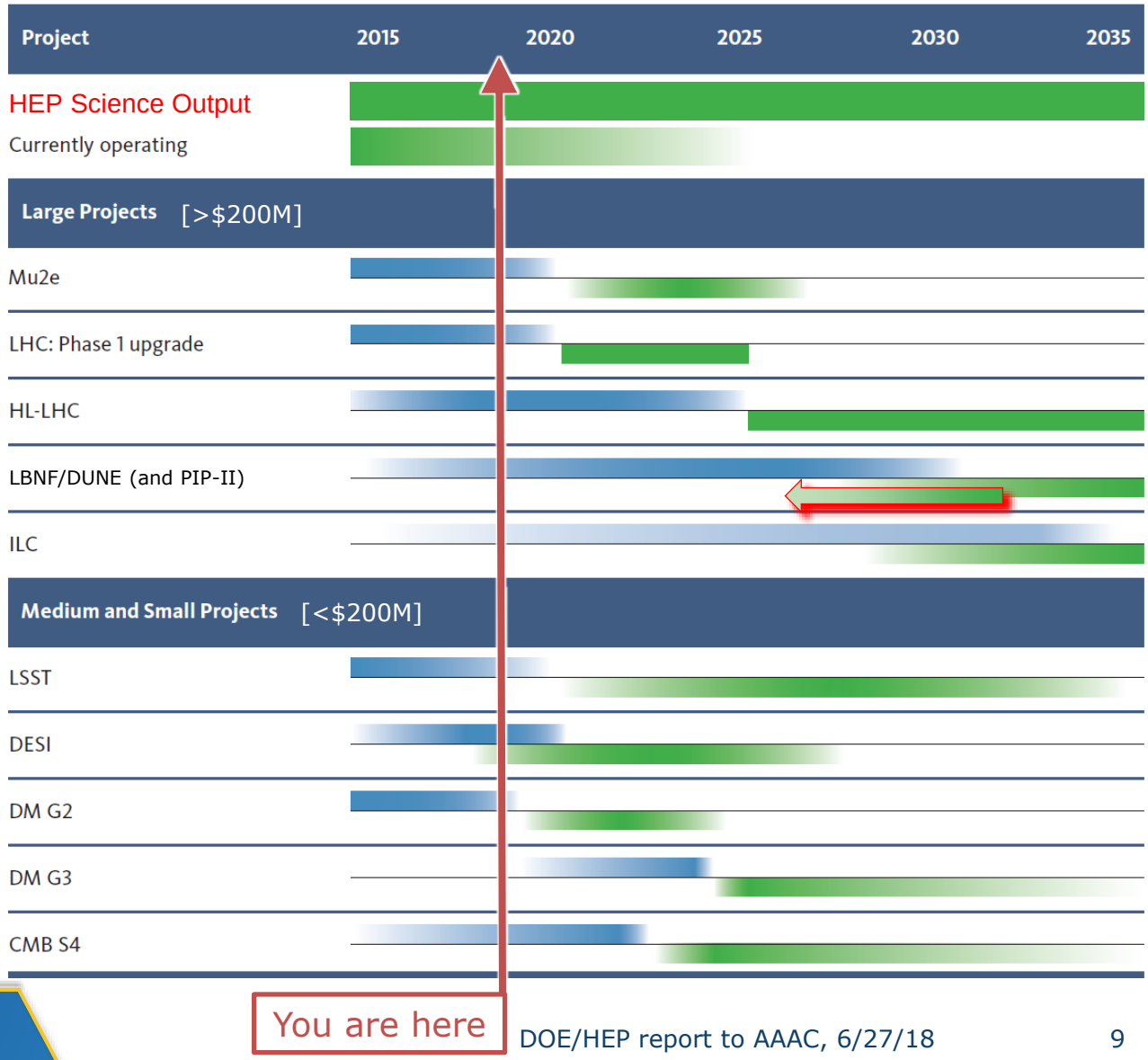
** Since 2011, three of the five science drivers have been lines of inquiry recognized with Nobel Prizes*

# P5 Construction and Physics Timeline

- P5 provided ten-year strategic plan in the context of a twenty-year global vision
- Carefully chosen investments will enable a steady stream of exciting new results for many years to come

***Legend:***

- ***Approximate Construction***
- ***Expected Physics***
- ***LBNF/DUNE Early Science***



# P5 – Balanced Program →Small Projects Portfolio

- HEP has funded a number of "small projects" and will continue to pursue timely physics opportunities with new experimental technique
  - Long list includes COHERENT, **ADMX-G2**, HPS, …
- Intermediate Neutrino Research Program workshop and FOA enabled PROSPECT, ANNIE
- Future Basic Research Needs (BRN) workshops may help define and prioritize additional opportunities for small project investments
  - Potential topic areas include: accelerator applications (compact accelerators), **Dark Matter**, detector R&D

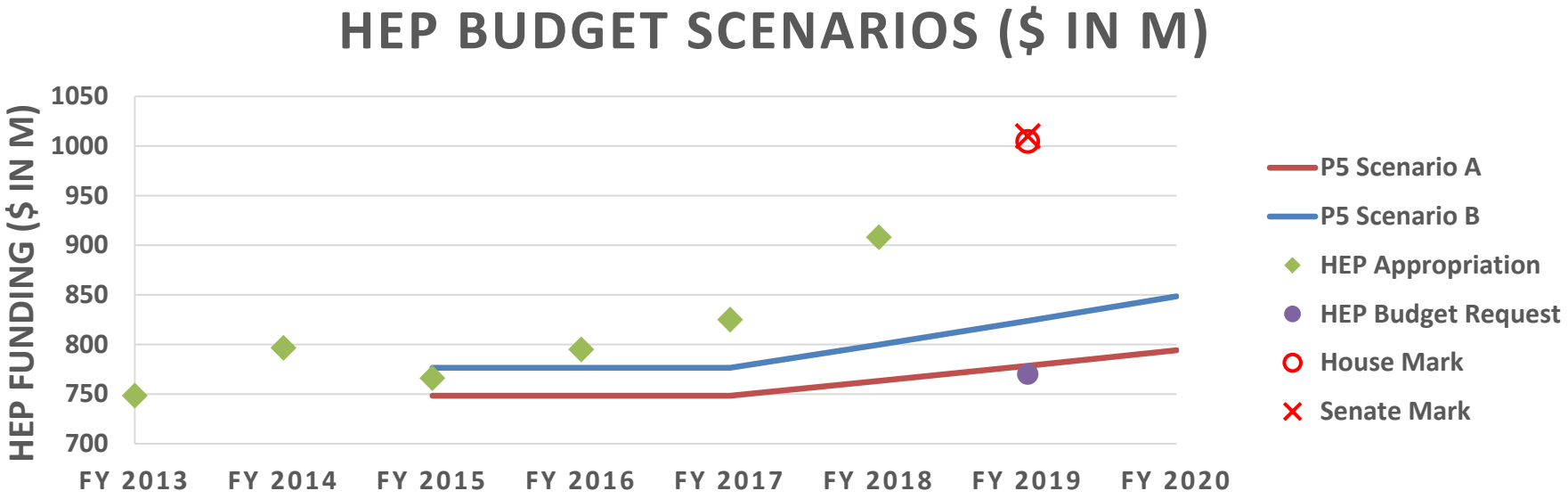
# Timeline for Updating the U.S. HEP Strategy

- The May 2014 P5 report was successful because it was well informed by the science community, including information from:
  - 2010 New Worlds, New Horizons in Astronomy and Astrophysics
  - 2012 Report of the Subcommittee on Future Projects of High Energy Physics (Japan)
  - 2013 European Strategy for Particle Physics Report
  - 2013 U.S. Particle Physics Community-driven "Snowmass" process
- The timeline of processes that impact strategic planning is:
  - 2018: Anticipated Japanese decision on ILC
  - 2018-20: New NAS Astronomy and Astrophysics Decadal Survey
  - 2019: Start of European Strategy for Particle Physics process
  - 2020: Release of updated European Strategy for Particle Physics
  - 2020: Earliest opportunity for National Science Board to approve obligating MREFC for HL-LHC
- **From a DOE perspective, the earliest that new "Snowmass," NAS Elementary Particle Physics Decadal Survey, and P5 processes could begin is 2020**
  - **Relative timing of Snowmass, P5, and NAS EPP Decadal survey to be determined**
  - **Enables receiving new P5 recommendations in time to inform the FY 2024/25 budget**
- U.S. community encouraged to work with international collaborators in developing other regional plans with a global vision for particle physics

# Budget

# 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 2018 appropriation enabled advancing P5 priority projects faster than schedule suggested by President's Budget Request
- FY 2019 President's Budget Request ($770M) reflects the P5 vision
  - House and Senate Marks would enable advancing schedule of high priority P5 projects



# 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 - All P5 priority projects are supported in the Request

- FY19 Budget Request reduces near-term science (research & operations) 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 prioritizes advances P5 science drivers and world-leading, long-term R&D in Advanced Technology, Accelerator Stewardship, and Quantum Information Science. Research drops below 40% of the program budget to enable executing P5 priority projects
  - Operations support enables world-class research at HEP User Facilities; support for ongoing experiments also reduced to make this possible

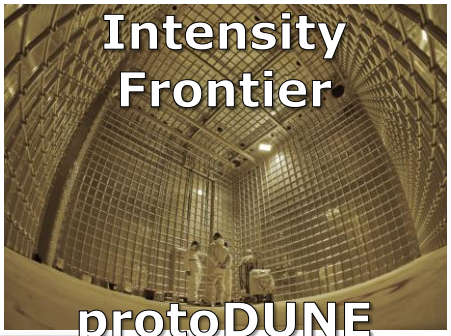
- The Administration and Congress support the overall P5 strategy
  - FY19 House Mark for HEP: **$1,004,510,000** ; FY19 Senate Mark for HEP: **$1,010,000,000**
- Final FY 2019 appropriation will define continued pace of P5 project execution

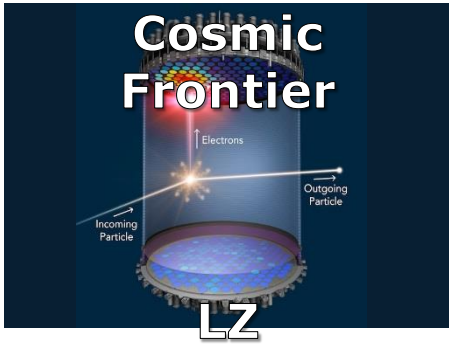
# FY 2019 Budget Highlights: Frontiers

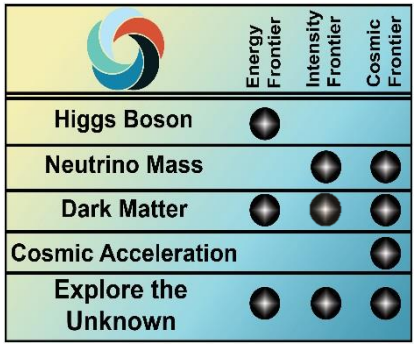
- Energy Frontier: Actively engage in successful LHC program and HL-LHC upgrades
  - The HL-LHC ATLAS & CMS detector upgrades (new MIE starts) and the HL-LHC Accelerator Upgrade Project are together considered one of P5's highest priority large projects
  - The U.S. will continue to play a leadership 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 projects - LZ, SuperCDMS-SNOLAB, DESI. LSST-camera project funding completed in FY18

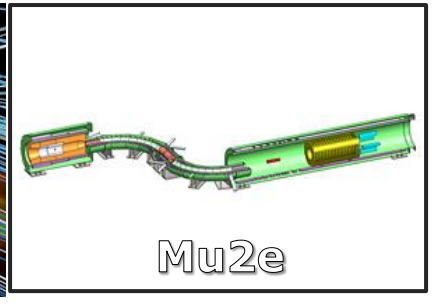



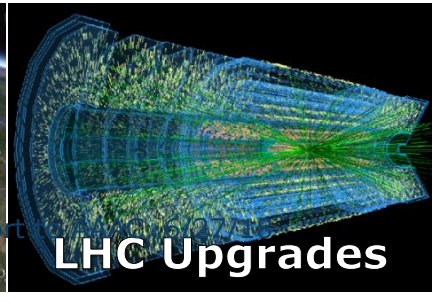



# FY19 Request: Projects & New Initiatives

- 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





# 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, for LHC operations & for Cosmic Frontier operations support.
  - 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

| 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** |

NOTE: The final FY18 funding for Cosmic Frontier may be different depending on Early Career awards etc.

# Cosmic Frontier: FY2017 – FY2019

- **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 |
| *LSSTcam* | *45,000* | *9,800* | *-* | *-9,800* |
| *DESI* | *12,800* | *20,000* | *11,400* | *-8,600* |
| *LZ* | *12,500* | *14,100* | *14,450* | *+350* |
| *SuperCDMS* | *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** |

# Portfolio Review

# DOE HEP Science Portfolio Review (2017-2018)

**HEPAP was charged (Oct. 2017) to carry out a Portfolio Review**
-- Modeled on NSF Portfolio Review and NASA Senior Reviews

**What, How:**

- Independent peer review of currently operating experiments supported by HEP
  - Overarching goal is to maintain and optimally execute the P5 plan
- Will focus on scientific impact and productivity of HEP-supported contributions with **narrow emphasis on P5 science drivers**.
- HEP will use the results to define a detailed implementation plan for P5 strategic vision in the FY19 to FY22 timeframe
- HEP will ensure that key officials in institutions or agencies that are partners in operating experiments are apprised of the plans, results and program decisions.
- **It is understood that many experiments have a much broader, high priority science program than the P5 science drivers!**

**Experiments reviewed**:

- Includes all currently-supported HEP experiments that have operated at least two years, and are continuing significant DOE-supported research &/or operations efforts in 2019 and beyond.
- There are 2 separate subpanels:
  1. **LHC subpanel** is chaired by Dr. Hugh Montgomery & covers ATLAS and CMS
  2. **"Main" subpanel** is chaired by Professor Paul Grannis and covers
     - **5 Cosmic Frontier experiments** (**Fermi-GLAST, AMS, HAWC, DES, eBOSS)**
     - **8 Intensity Frontier experiments** (Daya Bay, K0TO, MicroBooNE, Minerva, NA61/SHINE, NOvA, SuperK, T2K)

# HEP Portfolio Review – Timeline & Outcomes

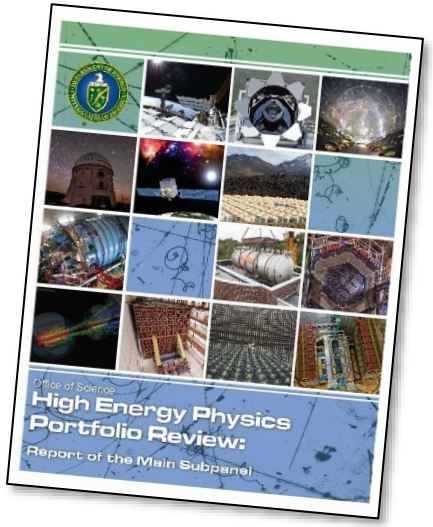
**HEPAP charged Oct. 2017**

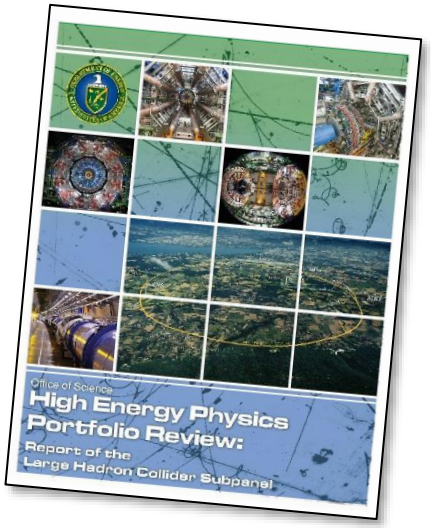
- *See Glen Crawford's HEPAP Dec. 2017 Presentation at* https://science.energy.gov/~/media/hep/hepap/pdf/201712/Day1_Crawford_2017-11-30_DOE_Portfolio_Review.pdf
- Charge letter, instructions and FAQ at https://science.energy.gov/hep/hepap/reports/

**February & March 2018** - Subpanels met face-to-face

**May 14-15, 2018 meeting - Portfolio Review Reports went to HEPAP & were accepted.**

-- Main Panel Report prioritized their impact on P5 science drivers in 4 Tiers, from absolutely essential to "less effective"




**HEP plan forward**

HEP will prioritize ongoing support for top-Tier(s)

- Lower Tier(s) to be ramped down over a few years depending on budgets, partnerships, external factors
- US contributions to LHC experiments also examined, with generally high praise and a few comments

➔HEP is now discussing with partners; Will be sending out guidance letters to each experiment.

# Portfolio Review – Draft main reoprt

**Draft report was presented and accepted at the May 2018 HEPAP meeting →**
https://science.energy.gov/~/media/hep/hepap/pdf/201804/Main_Panel_Report.pdf
https://science.energy.gov/~/media/hep/hepap/pdf/201804/PGrannis_HEPAP_201805.pdf

We summarize the definitions of the groups and the subpanel's recommendations for the 13 experiments. The ordering within a group is alphabetical.

**Group I** (*Experiments that should be pursued with highest priority*):
- DES, eBOSS, NOvA, T2K

**Group II** (*Experiments with outstanding promise and relevance to the P5 Science Drivers, but whose funding could be reduced somewhat in the event of severe budget shortfalls*):
- HAWC, MINERvA, NA61/SHINE

**Group III** (*Experiments that address the P5 Drivers in important ways, but for which a reduction in funding would cause less harm to the DOE/HEP program than in the case of Groups I or II*):
- Daya Bay, Fermi/LAT, MicroBooNE, SuperK

**Group IV** (*Experiments that require further demonstration of likely success, or whose future program is less effective in advancing the P5 Science Drivers*):
- AMS, KOTO

# Quantum Information Science

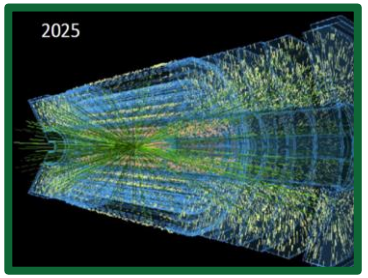
# Quantum Information Science (QIS)

- QIS has been identified as an important cross-cutting topic with potential impact across <u>all DOE Office of Science (SC) program offices</u>
  - See 11/29/17 Dear Colleague letter at: https://science.energy.gov/~/media/sc-2/pdf/presentations/2017/DOE-Office_of_Science_Dear_Colleague_Letter_on_QIS.pdf

- <u>For HEP</u>: Emphasis is on HEP mission, science drivers, and advancement of QIS in the context of the broader SC initiative

- FY 2018 Budget approved support for QIS (~ $15M).
- Funding Opportunity Announcement (FOA) for Universities & DOE Labs:
  - https://science.energy.gov/~/media/grants/pdf/lab-announcements/2018/LAB_18-1893.pdf
  - https://science.energy.gov/~/media/grants/pdf/foas/2018/SC_FOA_0001893.pdf
- Proposal review held & awards will be made by end of FY

- FY 2019 Request ~ $27M

# Computing planning

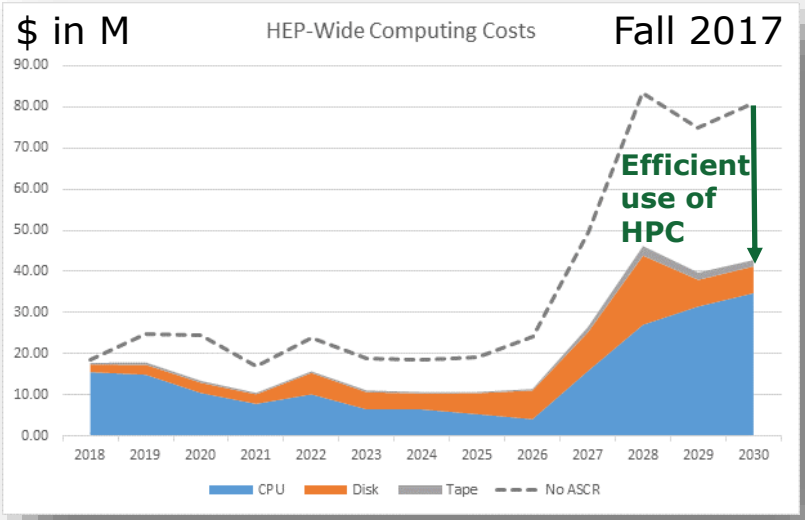
# Computing Strategy Development

- OHEP initiated a **consultative process** with the HEP community to:
  - More accurately capture the largest expected computing needs
  - Look for opportunities where economies of scale and optimal use of resources can close the gap

- **Inventory of HEP Computing Needs Roundtable Meeting** – *May 2018*
  - Focused on hardware, software, and personnel needs for the next decade
  - Identification of next steps
- **Commonalities Roundtable Meeting** – *later this year*
  - Focused on identifying common elements in software and workflows, HPC applicability, and integration with Exascale, HSF, S2I2, and other computing initiatives

# Updated HEP Computing Model

- In preparation for the Inventory Roundtable, the largest HEP experiments from all three frontiers were asked to provide a **more detailed estimate** of their expected computing needs
  - CPU, storage, network, personnel, and HPC portability
- Cost estimates for all experimental frontiers:
  - "Business as usual" (minimal additional HPC use): **$600M ± 150M**
  - With effective use of HPC resources this reduces to: **$275M ± 70M**
- By 2030 cost share by frontier is estimated to be:
  - ½ Energy Frontier
  - ¼ Intensity Frontier
  - ¼ Cosmic Frontier
- **A strategy encompassing all HEP computing needs is required!**



# PI Meeting

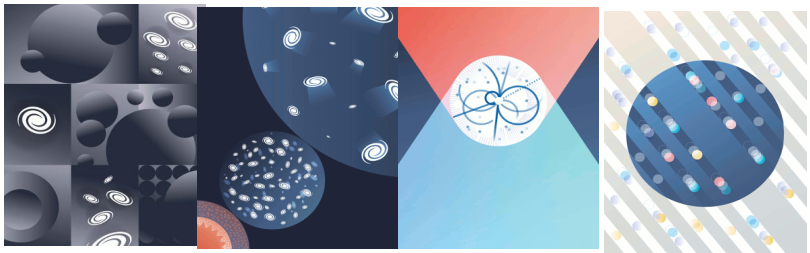
# 2018 HEP University PI Mtg

- To brief and guide the HEP community on future FOAs and to provide a status and overview of the DOE-supported HEP program, **we invite you to the next HEP Principal Investigator (PI) Meeting on August 22-24, 2018 in the Washington, D.C. area at:**
  - **Hilton Rockville/ Washington DC Hotel & Executive Meeting Center (1750 Rockville Pike, Rockville, MD)**
- Invitation is also extended to co-PIs on existing DOE grants, those PIs interested in applying to future DOE FOAs, and interested national laboratory staff.
- The format for the meeting will include the following:
  - General presentations during a plenary session covering the overall DOE-HEP program, budgetary issues, and different HEP FOAs at DOE to which PIs may apply
  - Parallel sessions led by individual DOE-HEP Program Managers (PMs) within the following subprograms: Energy, Intensity, and Cosmic Frontiers, Theoretical HEP, and Detector R&D, to provide detailed guidance on preparing comparative review applications for the merit review process, and the programmatic priorities and budgetary factors for the respective subprogram.
  - Opportunities for separate one-on-one sessions **(contact kathy.turner@science.doe.gov for Cosmic Frontier)**
- We believe the above meetings will benefit investigators and their research groups, and provide an opportunity for all researchers to better understand the DOE-HEP program. To take advantage of this opportunity, we encourage you to visit the PI Meeting website at:
  - **https://www.orau.gov/heppi2018/**
- This link contains details for PIs to make their individual hotel room reservations (*on their own*) as well as registration (*no fee*), and additional information on the agenda for different PI Meeting sessions, as they become available. Please check back periodically for any updates.
  - For questions, please contact Abid Patwa (abid.patwa@science.doe.gov) and Christie Ashton (christie.ashton@science.doe.gov).

# Cosmic Frontier – status & planning

# Cosmic Frontier Program

→Through ground-based telescopes & arrays, 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.



Dark Matter | Cosmic Acceleration | Explore the Unknown | Neutrino Mass

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

**Science and program priorities** are aligned with the 2014 P5 plan:

- P5 recommended a staged, 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**:

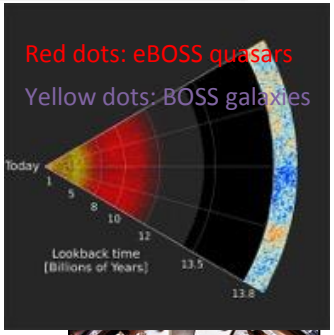
Dark Energy, Dark Matter, CMB, Cosmic-ray & Gamma-ray experiments

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

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

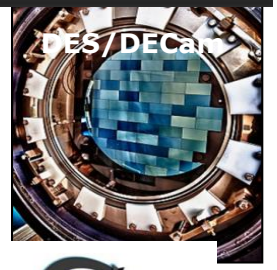
# Dark Energy

**Staged, complementary suite of** imaging and spectroscopic surveys (in partnership with NSF-AST)
**--** Will enable precision measurements to differentiate between: cosmological constant and/or new fields; or modification to General Relativity



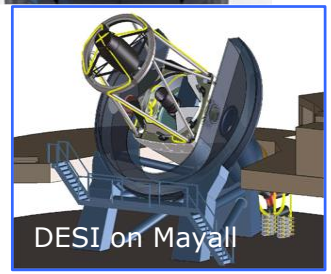

**Operating:**

- ***eBOSS*** – Stage III spectroscopic in New Mexico started in 2015 and will complete in 2020. with current HEP grant through mid-FY18 & being considered for few more years.
- ***Dark energy Survey (DES) –*** *Stage III* imaging in Chile started 5-year survey in late FY13




**In Fabrication phase:**

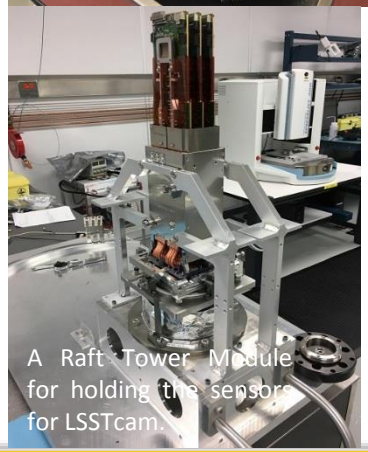
- **Large Synoptic Survey Telescope (LSST)**
  - Stage IV imaging
- ***Dark Energy Spectroscopic Instrument*** **(DESI)**
  - Stage IV spectroscopic

# Large Synoptic Survey Telescope (LSST)

The finished cryostat grid protected by a Plexiglas shield


Polishing the LSSTcam L3


A Raft Tower Module for holding the sensors for LSSTcam.

The Stage IV, next-generation, wide-field LSST facility in Chile is designed to provide deep images of half the sky every few nights, enabling study of the nature of dark energy using multiple cosmological probes.

DOE-HEP & NSF-AST partnership:

- NSF leads the LSST project and is responsible for the 8.4m telescope facility and data management system.
- DOE is responsible for providing the LSSTcam: Critical Decision (CD) 3 approval 2015; early delivery in FY20
- HEP MIE project funds completed in FY18; Support for Integration & Commissioning being funded on Operations budget.

**Status**

- NSF & DOE Project Status review Sept. 2017; next July 2018

- LSST Facility Operations phase being planned
  - NSF & DOE review of proposal in Dec. 2017
  - Activities start ramp-up in FY19
  - Full science operations planned to start FY23

- Dark Energy Science Collaboration (DESC) Operations Plan review May 2018

# Dark Energy Spectroscopic Instrument (DESI)

DESI's Stage IV spectroscopic survey will measure spectra of 35 million galaxies & quasars to map their 3-D positions and determine the growth of cosmic structure over 10 billion years; uses Baryon Acoustic Oscillation & Redshift Space Distortion growth + other methods

DOE leads the DESI experiment. The DESI project will provide the new spectrographs and associated systems to be mounted and operated on the NSF's Mayall telescope at Kitt Peak.

- HEP has MOU's w/NSF-AST to "lease" the Mayall telescope; ramping up partial support in FY16-18; full support for dark energy ops starting FY19

Status

- DESI project CD-3 approval June 2016
- Project status & Operations plan review, Feb. 2018
- Mayall shutdown in Feb. 2018
  - In June, the old top end was removed from the telescope and the new DESI top ring was lifted in. This accomplishes a major milestone and retires a significant risk for the project (see photos).
- Full dark energy survey operations starting FY20
  - All lenses polished & coated; all petals manufactured
  - DECaLS: DECam Legacy Survey, covering 2/3 of DESI footprint, had DR5 in Oct. 2017; now 75% complete

Kitt Peak – old top out & new top in for DESI (June 2018)

# Searches for Dark Matter (DM) particles

**HEP supports dark matter particle searches:**

- In the Energy Frontier at the LHC
- In the Intensity Frontier (e.g. dark photon searches)
- In the Cosmic Frontier
  - Direct detection searches
  - Indirect searches using cosmic-ray and gamma-ray surveys
- Theoretical studies & advanced technology R&D

## Direct Detection Searches

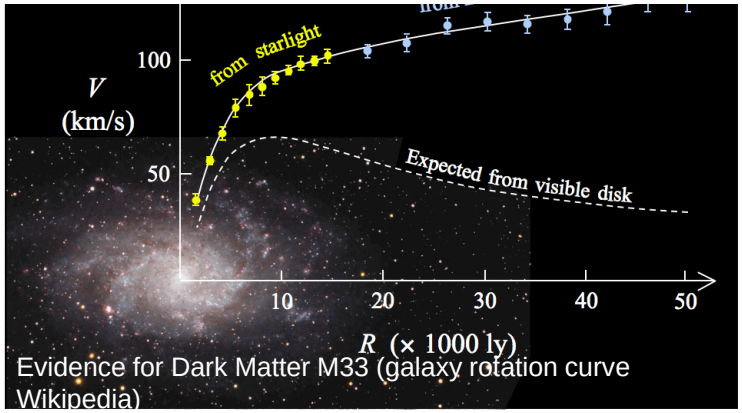
Staged suite of complementary direct detection experiments with multiple technologies to search for dark matter particles

- 3 Generation-two projects were selected by HEP & NSF-PHY in July 2014 following P5 report: **ADMX-G2, LZ, SuperCDMS-SNOLAB**
- High- and low-mass WIMP sensitivity; Axion (very low mass) searches

**Operating/Completed:**

- Completed HEP support for operations on current DM-Generation 1 (DM- G1) experiments in FY16/17: ADMX-II, LUX, CDMS-Soudan, DarkSide-50, COUPP/PICO, DAMIC -- some continue with other funding sources
- HEP's **ADMX-G2** axion search at UW

- Science operations started Jan 2017



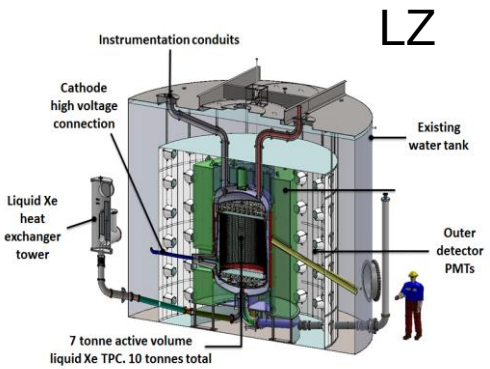
Evidence for Dark Matter M33 (galaxy rotation curve Wikipedia)

# Direct Detection Searches for Dark Matter (DM) cont.

**In Design, Fabrication**:

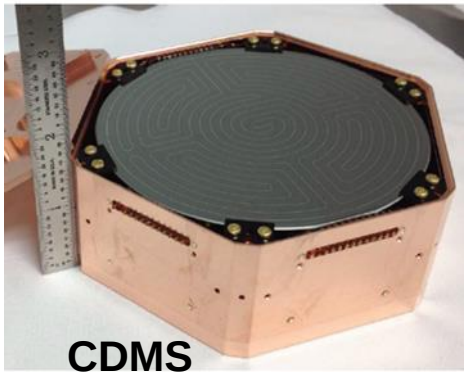
**LZ** at Homestake Mine in South Dakota (HEP)

- WIMP search through dual phase liquid Xe over ~10-1000 GeV mass
- In fabrication phase; CD-3 approved Feb 2017
- Science ops starts FY21
- Review of Project status & Operations plan in January 2018




**SuperCDMS-SNOLab** in Canada (HEP+NSF-PHY partnership)

- WIMP search using cryogenic solid-state crystals over ~1-10 GeV
- In final design phase; CD-2/3 approval in May 2018
- Science operations starts FY21
- CD2/3a review Jan. 2018; Review of Operations plan in June 2018



# Cosmic Microwave Background (CMB)

**Study cosmic acceleration (inflationary epoch) at energies near the Planck scale and dark energy and neutrino properties using the CMB, the oldest visible light (with NSF)**

**Operating**

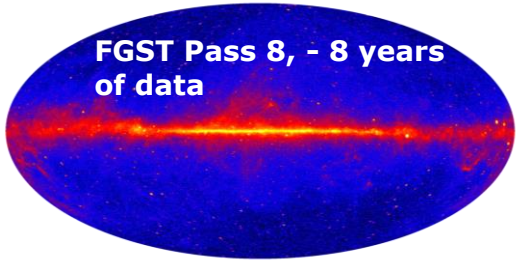
- ***SPT-3G*:**
  - NSF leads; HEP provided support towards major upgrade of camera
  - Operations started Jan. 2017
- Research-only activities on several current experiments; Lab involvement via Lab Directed R&D

# Cosmic-ray & Gamma-ray physics

- Use ground-based arrays, space telescopes, and an experiment on the International Space Station (ISS) to perform indirect searches for dark matter, fundamental physics & high energy acceleration mechanisms
  - Many significant inter-agency & international partnerships

**Operations - HEP Roles Completed**:

- VERITAS (2017), Pierre Auger (2016)



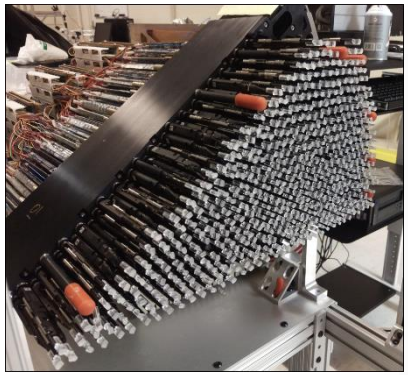

**Operations - HEP Roles Continue**:

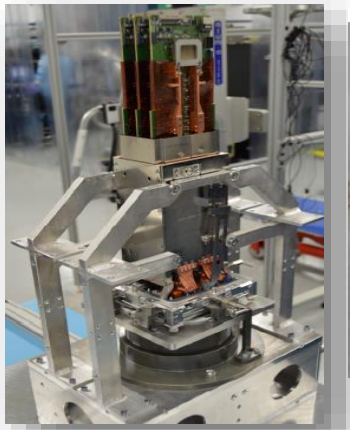
- *Fermi/GLAST (w/NASA); launched June 2008*
  - HEP is supporting the Instrument Science Ops Center at SLAC;
  - In coordination with NASA, HEP is planning to continue support of critical efforts at SLAC after 2018.
- *AMS (w/NASA) on the ISS; started 2011*
- *HAWC (w/NSF) in Mexico;* 5 year operations started early 2015

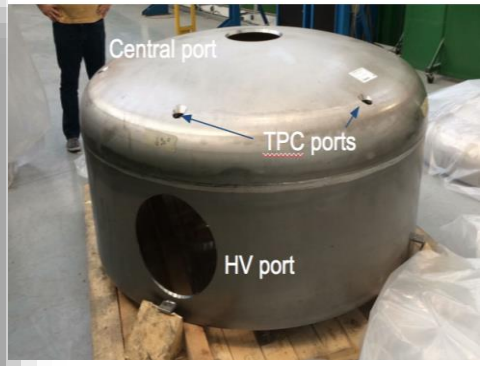


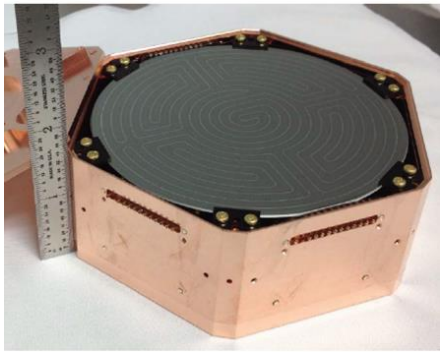
# Cosmic Frontier – Major Item of Equipment (MIE) Projects in Fabrication

| 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. 2017 Facility Ops, May 2018 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 May 2018 | (mid-2020) | Jan. 2018 Project; June 2018 Ops plan |







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

# Cosmic Frontier – Operating Experiments

| Portfolio Review experiments in black | | |
|---|---|---|
| **Experiment** | **Location** | **Science Operations Started** |
| AMS | ISS | May 2011 launch |
| FGST | space | June 2008 launch |
| HAWC | Mexico | March.2015 |
| DES | Chile | Sept. 2013 |
| eBOSS | New Mexico | July 2014 |
| ADMX-G2 | University of Washington | Jan.2017 |
| SPT-3G | South Pole | Feb.2017 |

# Cosmic Frontier – Future Planning to carry out P5

**Planning to carry out P5 plan**: Laying ground work

- These are mainly science studies; R&D funds are VERY limited. Labs using internal R&D funds to develop future plans & technologies

**➔CMB Stage 4 (CMB-S4)**

As recommended by P5, DOE-HEP is planning to participate in a next-generation, 10x more sensitive array, the CMB Stage 4 (CMB-S4)

The Astronomy and Astrophysics Advisory Committee (AAAC) accepted the CMB-S4 Concept Definition Taskforce (CDT) report in October 2017

- Described science goals, technical requirements, and a strawman concept
- Total project cost ~ $400M
  - https://www.nsf.gov/mps/ast/aaac/cmb_s4/report/CMBS4_final_report_NL.pdf
  - https://science.energy.gov/~/media/hep/hepap/pdf/201712/Day2/Lawrence_CMB-S4_CDT_for_HEPAP_12-01-2017.pdf

Following the CDT:

- DOE/HEP and NSF continue meetings
- HEP lab continue significant technology R&D efforts
- HEP lab groups, in coordination with the CMB-S4 collaboration, have set up a pre-Project Design Group (pPDG) for pre-conceptual planning and studies; will also investigate project strategies (partners, timeline, implementation options & funding possibilities)

# Cosmic Frontier – Future Planning to carry out P5, cont.

**➔Dark Energy**:

- DOE-HEP asked for community input on optimizing science in DESI/LSST era and possible future projects
- Community Workshop held November 2017 at LBNL; White Paper posted at arXiv:1802.07216
- Presentation at HEPAP meeting on 5/15/18

**➔Dark Matter:**

**P5 recommended the search for dark matter particles as high priority science & to maintain a diversity of project scales in the program (i.e. ensuring small projects too)**

**Planning for a new initiative for small dark matter project(s).**

- Dark Matter Community workshop held March 2017 to update identification of scientifically compelling areas to search, see https://arxiv.org/abs/1707.04591
  - can be accelerator or non-accelerator based.
- Process is under development for the next step (see slide on Basic Research Needs study)

**Community Studies for the Future:**

- National Academies of Sciences: Astronomy/Astrophysics Decadal Survey (current plan is to be carried out late 2018 through spring 2021).

# HEP Basic Research Needs (BRN) studies

- SC's Office of Basic Energy Sciences initiated the BRN approach in 2002
- Purpose is to help to define directions and make the case for major new efforts
- Targeted topics defined by, and workshop charge issued by, SC program office
- Participation & attendance is limited and by invitation
- Workshop Chair & Co-Chairs develop agenda & select topic-leads (w/Program office input)

BRN study on **New Opportunities for Dark Matter**

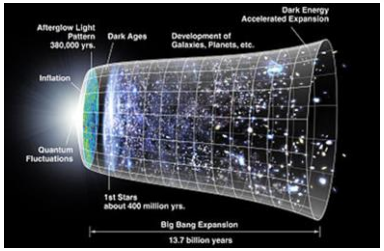
- March 2017 community workshop held to determine & identify scientifically compelling areas to search and whether there are possible concepts for new experiments or studies to address these. See *White Paper: https://arxiv.org/abs/1707.04591*

- Considering P5 recommendations and the current landscape, HEP is developing Dark Matter BRN study:
  - To provide priority science directions and areas in which to search [that will provide significant science return and advancement]
    - Of these, describe which would be suitable to be pursued with focused small projects in the HEP program [i.e. that would be best carried out using DOE infrastructure and capabilities].

- Co-Chairs have been identified and are starting to organize efforts.

- HEP is also considering holding a future BRN on Detector R&D

# Summary & Conclusion




- HEP is maintaining the core of the DOE Science Mission
  - 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.

- looking forward to participation in the National Academy of Science's 2020 Astronomy & Astrophysics Decadal Survey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