U.S. DEPARTMENT OF ENERGY | Office of Science

Office of High Energy Physics (HEP) Program Status & Plans

AAAC Meeting at NSF

February 25, 2019

Kathleen Turner

Program Manager for the Cosmic Frontier

Office of High Energy Physics

U.S. DEPARTMENT OF
ENERGY | Office of Science

DOE Mission, Guidance

DOE Office of High Energy Physics (HEP) Program Mission

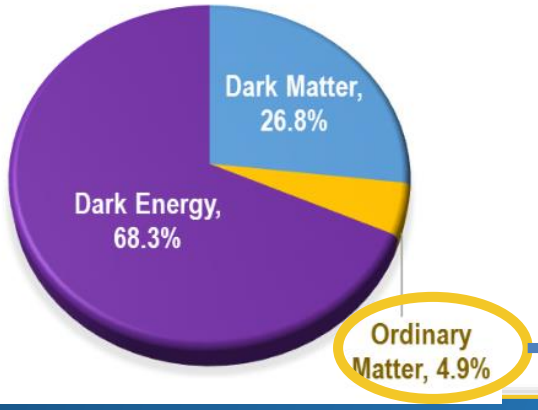
DOE is a mission-oriented agency, and includes **maintaining a vibrant U.S. effort in science and engineering as a cornerstone of our economic prosperity with clear leadership in strategic areas.**

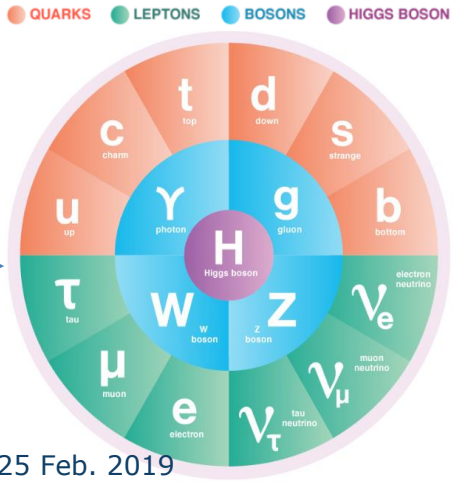
HEP's mission is to understand how the universe works at its most fundamental level

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

HEP fulfills its mission by

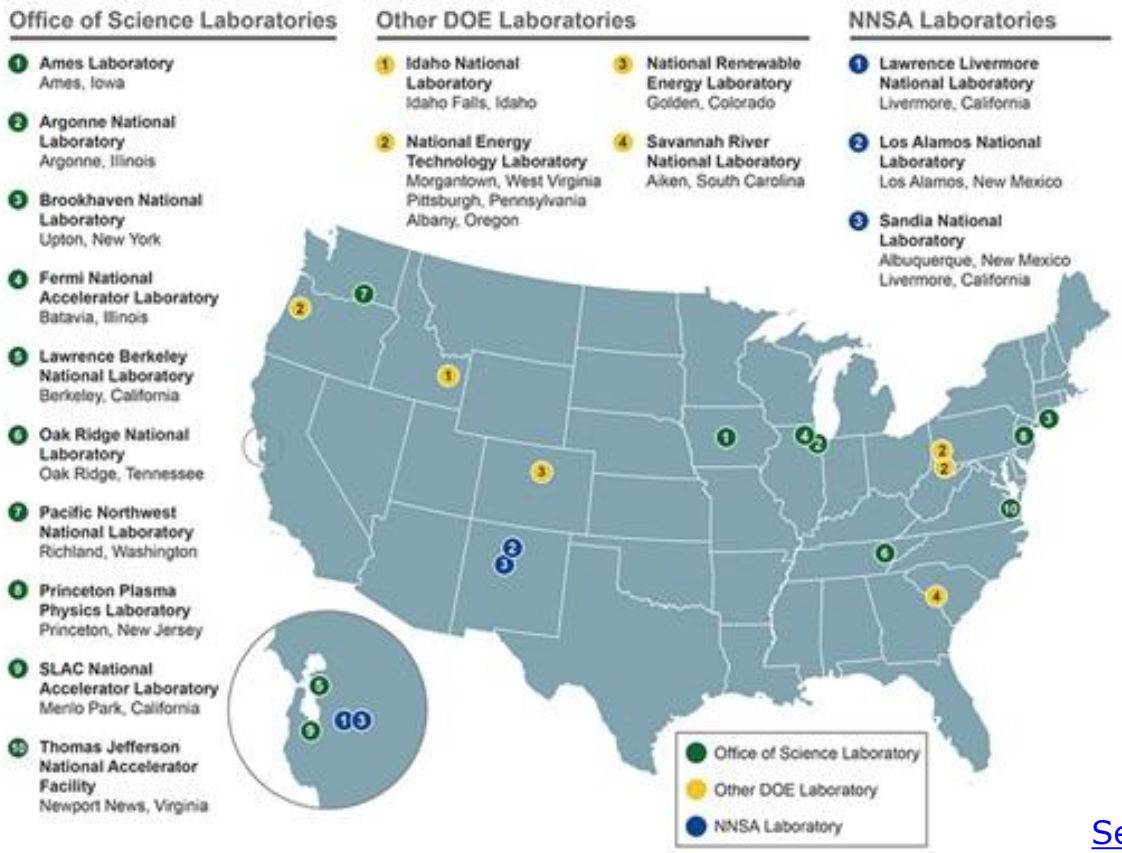
- Building projects that enable discovery science
- Operating facilities that provide the capability for discoveries
- Supporting a research program to produce discovery science





DOE National Labs – Our Crown Jewels

Together, the 17 DOE laboratories comprise a preeminent federal research system, providing the Nation with strategic scientific and technological capabilities.



The laboratories:

- Execute long-term government scientific and technological missions, often with complex security, safety, project management, or other operational challenges;
- Develop unique, often multidisciplinary, scientific capabilities beyond the scope of academic and industrial institutions, to benefit the Nation's researchers and national strategic priorities; and
- Develop and sustain critical scientific and technical capabilities to which the government requires assured access.

See https://science.energy.gov/laboratories/

HEP Program Guidance

FACA panels & subpanels provide official advice:

- **High Energy Physics Advisory Panel (HEPAP)**
  - Advises **DOE & NSF**: Provides the primary advice for the HEP program
  - Subpanels: The Particle Physics Project Prioritization Panel ("P5") provides the Strategic Plan for HEP

- **Astronomy and Astrophysics Advisory Committee (AAAC)**
  - Advises **DOE, NASA, & NSF** on issues of overlap, mutual interest and concern
  - Subpanels: CMB-S4 Concept Definition Taskforce (2017), Gemini-Blanco-SOAR Telescopes roles (2019)

Advice Also Provided by: National Academy of Sciences (NAS)

- **Decadal Surveys in Astronomy & Astrophysics**, Elementary Particle Physics
- Board on Physics & Astronomy (BPA), Committee on Astronomy & Astrophysics (CAA)

Other Input & Coordination

- Community studies & input
  - e.g. Snowmass, Dark Energy Task Force, APS/DPF
  - Basic Research Needs (BRN) studies as start of process to develop new HEP initiatives

Interagency Coordination

Formal advice:

HEPAP – advises DOE & NSF

AAAC – advises NASA, NSF, DOE

National Academy of Science studies – Decadal Surveys, BPA, CAA etc.

Coordination:

DOE-HEP, NSF-AST, PHY, OPP - Regular meetings about 2 times/year

Regular Joint Oversight Group (JOG) or Joint Coordination Group (JCG) meetings for particular projects or experiments.

Invited to each others reviews & meetings.

U.S. DEPARTMENT OF ENERGY | Office of Science

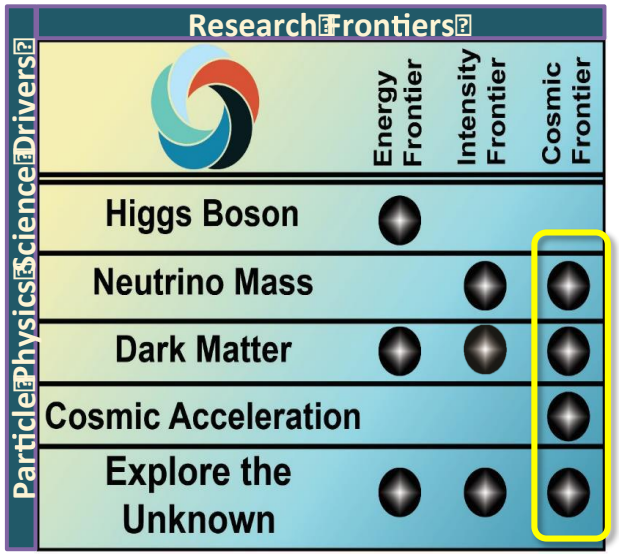
P5 Strategic Plan & Implementation

HEPAP P5 Strategic Plan

As part of a mission agency, HEP uses a community-driven strategic planning process to identify the projects that will provide significant leaps in science and capabilities

- U.S. High Energy Physics Advisory Panel convened P5 to develop a plan to be executed over a ten-year timescale in the context of a 20-year global vision for the field; within several funding scenarios
- The 2014 P5 report enables discovery science with a balanced program that deeply intertwines U.S. efforts with international partners

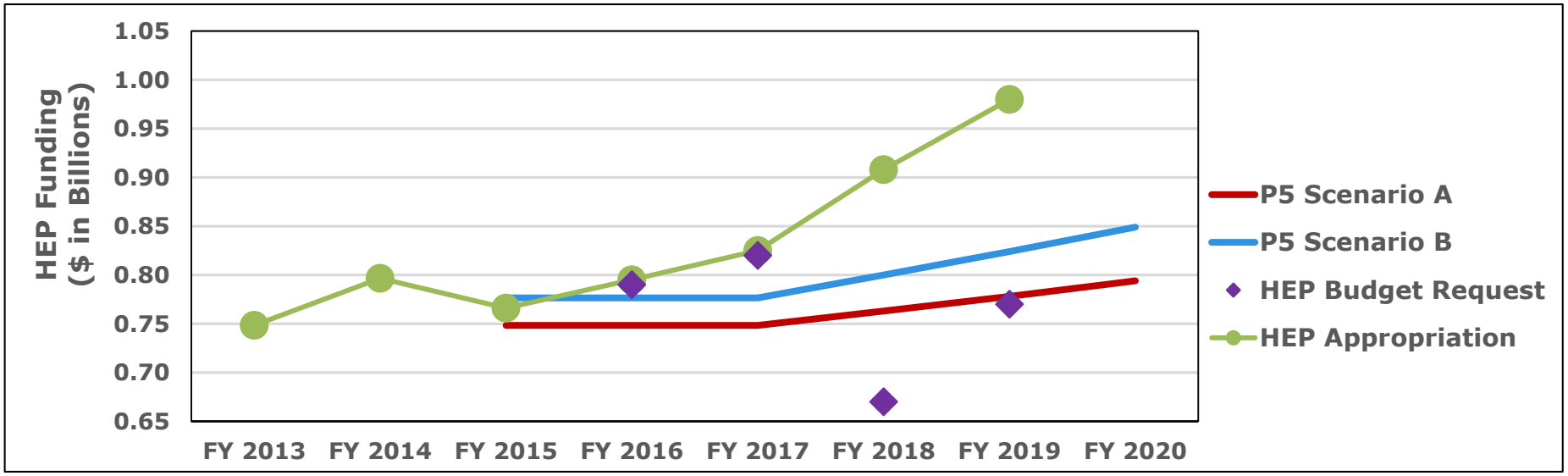
2014 P5 Report: Strategic Plan & 5 HEP Science Drivers



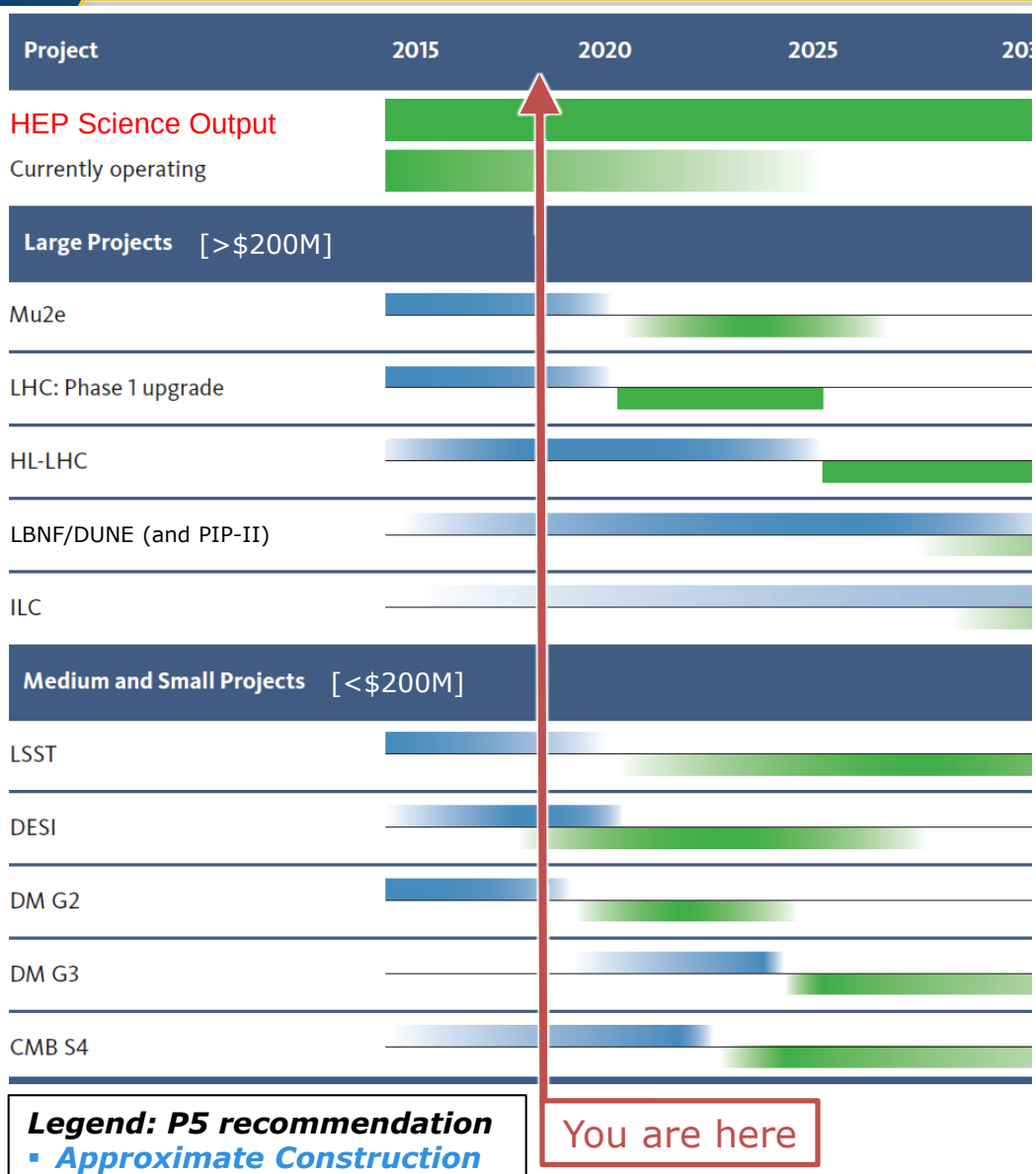
U.S. Congress Supports P5 Strategy

- FY 2019 Senate Energy and Water Development Appropriations Report:
  - "The Committee recommends $1,010,000,000 for High Energy Physics. **The Committee strongly supports the Department's efforts to advance the recommendations of the Particle Physics Project Prioritization Panel Report [P5],** which established clear priorities for the domestic particle physics program…"

"Four years into executing the P5, the Committee commends the Office of Science and the high energy physics community for achieving significant accomplishments and meeting the milestones and goals set forth in the strategic plan…"



P5 Implementation Status – FY 2019



Operating:

- Muon g-2 (1st beam 2017)
- Broad portfolio of small experiments including ADMX-G2, SPT-3G, DES, eBOSS

All projects on budget & schedule

- LHC detector upgrades: on track for 2019/20 installation
- Mu2e : 1st data in 2020
- DESI, DM-G2(SuperCDMS, LZ) – fabrication completes FY20
- HL-LHC accelerator and detector upgrades started on schedule
- LSST camera fabrication (last funds FY18); I&T, commissioning starting
- LBNF/DUNE & PIP-II schedules advanced due to strong support by Administration & Congress

NOT YET IN CD process:

- **CMB-S4: developing concept with technically-driven schedule & input to Astro2020; HEP plans FY19 CD0**
- DM-G3: R&D limited while fabricating G2
- ILC: cost reduction R&D while waiting for decision from Japan

U.S. DEPARTMENT OF
ENERGY | Office of Science

Budgets

FY 2019 Appropriations (and C.R.)

- **On September 21, 2018**, President Trump signed into law a bipartisan minibus (Senate 92-5, House 377-20) spending package consisting of three FY 2019 spending bills: Energy and Water, Military Construction and Veterans Affairs, and Legislative Branch.

➔ **Department of Energy was funded for FY19**

FY2019 Language:

High Energy Physics.—Within available funds, the agreement provides $15,000,000 for PIP-II; $6,250,000 for ongoing efforts for commissioning and initial operation of the camera for the Large Synoptic Survey Telescope Camera; $10,000,000 to continue the upgrade of FACET II; $105,000,000 for the HL-LHC Upgrade Projects; and $22,450,000 to complete the dark energy and dark matter experiments, of which $5,450,000 is for DESI and $14,450,000 is for LUX ZEPLIN.

FY 2019 HEP Enacted Budget

HEP Funding Category ($ in K)	FY 2017 Actual	FY 2018 Actual	FY 2019 Enacted	FY 2019 vs. FY 2018
Research	344,043	359,177	380,847	+21,670
Facilities/Operations	258,696	270,488	260,803	-9,685
Projects	222,261	278,335	338,350	+60,015
Total	**825,000**	**908,000**	**980,000**	**+72,000**

- **FY 2019 Appropriations supports the SC and P5 priorities**
  - SC: interagency partnerships, national laboratories, accelerator R&D, Quantum Information Science (QIS)
- **P5 strategy continues to define investments in future of the field for HEP**
- **FY 2019 HEP Budget continues support for P5-guided investments in the mid- and long-term program**
  - "Building for Discovery" by supporting highest priority P5 projects to enable future program
  - Research support advances P5 science drivers and world-leading, long-term R&D in Advanced Technology, Accelerator Stewardship, and Quantum Information Science
  - Experimental & Facility Operations support enables world-class research

FY19 HEP enacted Budget $980M: Balancing Research, Operations and Projects

Project funding of $338.4M (34.5%) was increased above the Request; many projects are fully controlled by Language

- LBNF/DUNE +35M over FY 2018, and +17M over Request

Fully funded as of FY19:

- FACET-II
- LHC detector upgrades: on track for 2019/20 installation
- Mu2e : 1st data in 2020
- DESI, DM-G2(SuperCDMS, LZ) complete fabrication FY20
- Note: LSST camera final fabrication funding was provided in FY18

FY19 Accelerated Project funding:

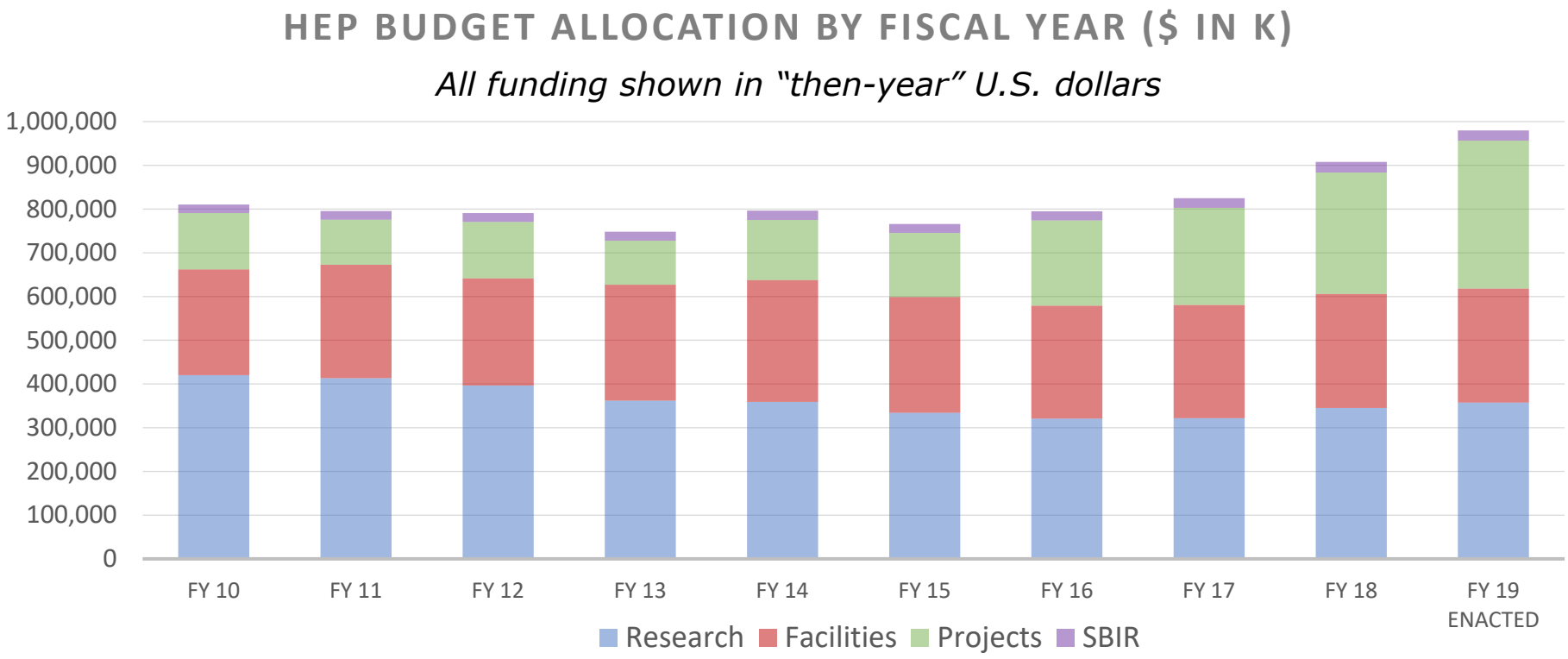
- Creates opportunities to launch new initiatives by mid-2020s
- Confronts new risks (facility capacity, modernizing infrastructure)
- Increases pressure to deliver on science earlier

Research & Operations funding is $641.6M (65.5%)

- Strong support provided; funding still facing pressure
  - Research budget provides support for scientists in all phases of an experiment
  - Operations provides support for experimental/facility operations & data processing

Budget: Overall HEP Trend

- P5 strategy continues to define investments in future of the field
- FY 2019 Enacted increases project funding above Request
  - Profiles for high-priority projects recommended by P5 continue to ramp up
  - **Research funding could face pressure even if overall HEP budget rises**



HEP Project Status - Line Item Construction & Major Item of Equipment (MIE)

Final Year of Project Funding

Subprogram	TPC ($M)	CD Status	CD Date
INTENSITY FRONTIER			
Long Baseline Neutrino Facility / Deep Underground Neutrino Experiment (LBNF/DUNE)	1,300 – 1,900	CD-3A	September 1, 2016
Proton Improvement Project (PIP-II)	653 - 928	CD-1	July 23, 2018
Muon g-2 (FY 2017)	46.4	CD-4	January 16, 2018
Muon-to-Electron Conversion Experiment (Mu2e) (FY 2019)	273.677	CD-3	July 14, 2016
ENERGY FRONTIER			
LHC ATLAS Detector Upgrade (FY 2017)	33	CD-3	November 12, 2014
LHC CMS Detector Upgrade (FY 2017)	33	CD-4A	September 19, 2017
High-Luminosity LHC (HL-LHC) Accelerator Upgrade	208 - 252	CD-1/3A	October 13, 2017
High-Luminosity LHC (HL-LHC) ATLAS Detector Upgrade	149-181	CD-1	September 21, 2018
High-Luminosity LHC (HL-LHC) CMS Detector Upgrade	125-155	CD-0	April 13, 2016
COSMIC FRONTIER			
LUX-ZEPLIN (LZ) (FY 2019) (FY 2019)	55.5	CD-3	February 9, 2017
Super Cryogenic Dark Matter Search - SNOLAB (SuperCDMS-SNOLAB)	18.6	CD-2/3	May 2, 2018
Dark Energy Spectroscopic Instrument (DESI) (FY 2019)	56.328	CD-3	June 22, 2016
Large Synoptic Survey Telescope Camera (LSSTcam) (FY 2018)	168	CD-3	August 27, 2015
ADVANCED TECHNOLOGY R&D			
Facility for Advanced Accelerator Experimental Tests II (FACET-II) (FY 2019)	25.6	CD-2/3	June 8, 2018

FY 2019 Funding by Subprogram

HEP Funding Category ($ in K)	FY 2017 Actual	FY 2018 Actual	FY 2019 Enacted	FY 19 vs. FY 18
Energy Frontier	154,274	183,219	238,920	+55,701
Intensity Frontier	242,924	247,048	240,980	-6,068
Cosmic Frontier	135,988	119,630	101,036	-18,594
Theoretical, Computational, and Interdisciplinary Physics	60,251	76,176	89,834	+13,658
Advanced Technology R&D	124,447	125,643	113,506	-12,137
Accelerator Stewardship	13,616	15,885	15,724	-11
Construction (Line Item)	93,500	140,400	180,000	+39,600
Total	**825,000**	**908,000**	**980,000**	**+72,000**

- Energy: +54M HL-LHC Projects
- Intensity: -8.1M PIP-II other project costs
- Cosmic: -25M LSSTcam, DESI, SuperCDMS-SNOLAB projects; Operations ramps up
- Theory, Computational, and Interdisciplinary: +9.5M Quantum Information Science (QIS)
- Advanced Technology: -9M Accelerator Improvement Projects at LBNL and SLAC

Quantum Information Science (QIS)

QIS has been identified as an important cross-cutting topic with potential impact across all DOE Office of Science (SC) program offices

HEP-QIS Sub Program (Coordinated with broader SC and national initiative)

- Forge new routes to scientific discovery along the HEP mission and P5 science drivers invoking interdisciplinary advances in QIS,
- Contribute to QIS using expertise, techniques, and technology developed in HEP community
- Develop effective interdisciplinary consortia that positively impact both HEP and QIS fields

- Awards for FY 2018 HEP Funding Opportunity Announcement (FOA) and Lab Announcement Quantum Information Science Enabled Discovery (QuantISED) have been announced:
- https://www.energy.gov/articles/department-energy-announces-218-million-quantum-information-science
- The FY18 specific HEP awards (~ $18M) are listed at: https://science.energy.gov/hep/
  - **Many overlap with Cosmic Frontier potential future projects.**
- **FY 2019 QIS funds ~ $27M**

Future Computing Update

- The fields demands for computing and supercomputing are growing
  - See Jim Siegrist's May HEPAP presentation: https://science.energy.gov/hep/hepap/meetings/201805/
  - As an example, this year NERSC requests were up 50% over 2018
  - ASCR's Exascale Computing project will play an important role in satisfying this demand, but much of HEP code is not ready for Exascale

- We have charged the Center for Computational Excellence (CCE) to be a matchmaker between HEP and ASCR experts to look at several example codes
  - Assess the level of effort needed to make HEP code ready for Exascale
  - Assess the degree the issues and potentially solutions are shared
    - Across experiments and Frontiers
  - We have invited the Laboratories to submit Field Work Proposals (FWPs) for this activity
  - CCE leadership will provide a program plan in near future
  - NSF launched the Institute for Research and Innovation in Software for High-Energy Physics (IRIS-HEP) to tackle similar issues from the university perspective

- The first "pre-Exascale" computer, Summit, has been delivered to Oak Ridge and is in "Early Science" phase (open to regular use next year)
  - The follow-on, Aurora, is planned for 2021
  - First codes to run at scale were 3 of the largest cosmology simulations ever

- Storage and networking is next on our agenda

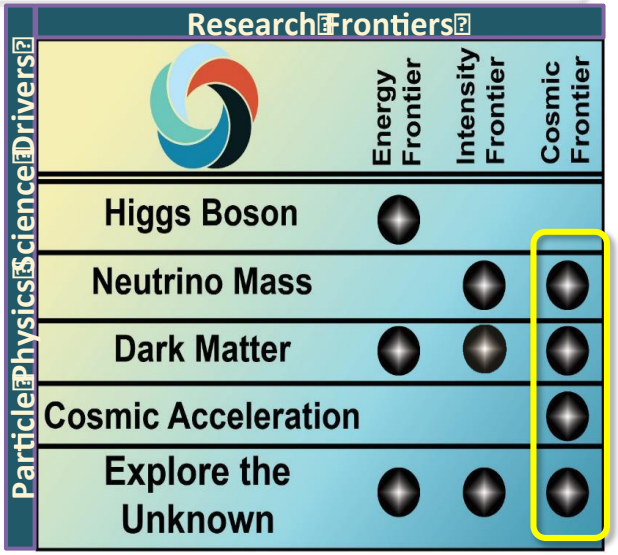
U.S. DEPARTMENT OF ENERGY | Office of Science

Cosmic Frontier Experimental Research

Program Managers:
Kathy Turner
Drew Baden (IPA)
Karen Byrum (Detailee)
Eric Linder (IPA)

Cosmic Frontier Experimental Research Program

Address P5 science drivers using naturally occurring cosmic phenomena via ground-based telescopes & arrays, space missions, and deep underground detectors



Cosmic Acceleration:
- Imaging & Spectroscopic surveys to determine the nature of **Dark Energy**
- Study the Inflation using its imprint on the cosmic microwave background (**CMB**)

Dark Matter:
- Direct Detection **Dark Matter** particle searches
- Cosmic-ray & Gamma-ray studies provide indirect searches for dark matter particles & searches for New Physics; also accelerator-based searches (Intensity & Energy Frontier)

Neutrino Mass: Dark Energy and CMB experiments place unique constraints neutrino masses

Explore the unknown: through Cosmic- and Gamma-ray experiments

Cosmic Frontier – Partnerships, Coordination, Planning

NSF and NASA partnerships on most experiments

- Regular Joint Oversight Group (JOG) or Joint Coordination Group (JCG) meetings

Most experiments and projects have international partners or contributions and some also have private contributions

-- International Research Committees support coordination of needs & resources (FGST, LSST-DESC)

Significant contributions & support from other HEP areas, including Theory, Advanced Detector Development, Computational HEP, QIS

Cosmic Frontier – coordination & planning

- Basic Research Needs (BRN) study for Dark Matter New Initiatives
- Cosmic Visions Dark Energy study
- Astro-Particle International Forum (APIF) – Agency-level international group
- Tri-Agency Group (TAG) – DOE, NASA, NSF-AST coordination

Cosmic Frontier FY 2019 Budget

Cosmic Frontier ($ in K)	FY 2017 Actual	FY 2018 Actual	FY 2019 Enacted	FY 19 vs. FY 18
Research	45,990	47,008	50,741	+3,733
Facilities/Operations	13,353	17,300	20,076	+2,776
Projects	74,375	52,835	27,350	-25,485
LSSTcam	*45,000*	*9,800*	*-*	*-9,800*
DESI	*12,800*	*20,000*	*9,350*	*-10,650*
LZ	*12,500*	*14,100*	*14,450*	*+350*
SuperCDMS	*3,400*	*7,400*	*2,550*	*-4,850*
SBIR/STTR	2,270	2,487	2,869	+382
Total	**135,988**	**119,630**	**101,036**	**-18,594**

- **Research:** World-leading research efforts (scientist support) to carry out all phases of an experiment including design, fabrication, commissioning and operations phases, planning for future experiments, including CMB-S4.
- **Operations:** Commissioning and Operations Funding is ramping up with efforts on LSSTcam, early planning for LSST facility and science operations, and planning, commissioning, and pre-operations activities for DESI, LZ, and SuperCDMS-SNOLAB. Support for the currently operating experiments continues on planned schedule.
- **Projects:** All Cosmic Frontier projects are fully supported. FY19 completes the funding for DESI, LZ, SuperCDMS-SNOlab. LSSTCam funding completed FY18.

Dark Energy

Precision measurements to differentiate between: cosmological constant and/or new fields; or modification to General Relativity

Staged, complementary suite of imaging and spectroscopic surveys to determine its nature (in partnership with NSF-AST)

Operating:

– *eBOSS* (spectroscopic) started in 2015, ends Feb 2019

– *DES* (imaging) started 5-year survey in late FY13, ended Jan 2019

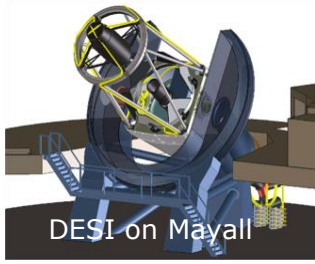
In Fabrication phase:

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

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

Planning for the Future

- Cosmic Visions Group
- Three Agency Group (TAG)

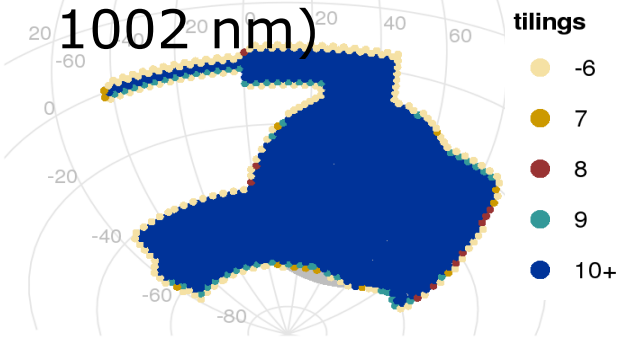


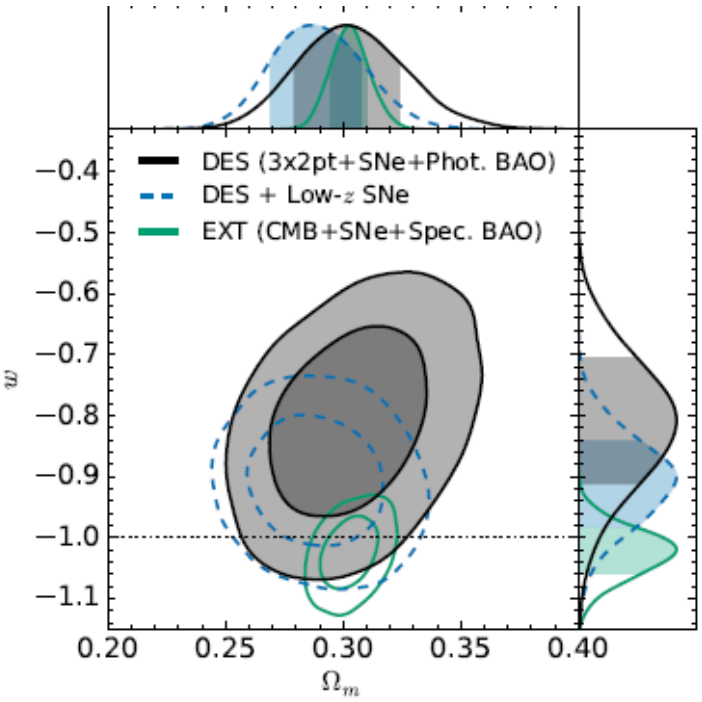
Dark Energy Survey

DOE-HEP partnership with NSF-AST: DOE provided DECam; support DECam operations for DECam & computing (with NSF)

- Completed Observations Jan 9th, 2019
  - ~5100 sq. deg. in 5 filters (grizY), each w/ ten 90s exposures. Successfully met all survey metrics.
- 221 scientific publications through Jan. 31, 2019, ~70 in the past 12 months on range of topics spanning astrophysics from solar system to cosmology
- Public Data Release "DR1" based on 1st 3 years data (Y1-Y3) has > 630 users, 6 Tb data delivered
- Among the many cosmology highlights in the past year:
  - Constraints on Extended cosmological models from DES Y1 Weak Lensing and Galaxy Clustering (WL)*
  - Cross Correlation of DES WL signal w/ Planck and SPT**
  - Cosmology from 207 DES Y1-Y3 spect.-typed SN1a^
  - Combined DES Y1 WL & Y1 LSS & SN1a cosmology^^
- Now concentrating on cosmology through Y3 (later this year) & on producing Y6 data products for analysis, Y6 cosmology to follow

e.g. z-band (850-1002 nm)





Large Synoptic Survey Telescope (LSST) - Status

DOE-HEP & NSF-AST (lead) partnership:

- LSST is under construction
- HEP responsible for LSST camera (SLAC); last funding FY18
- HEP support for I&T commissioning ops started FY18
- Full science ops start FY23
- LSST Facility Operations – funding has started for planning & ramp up has started

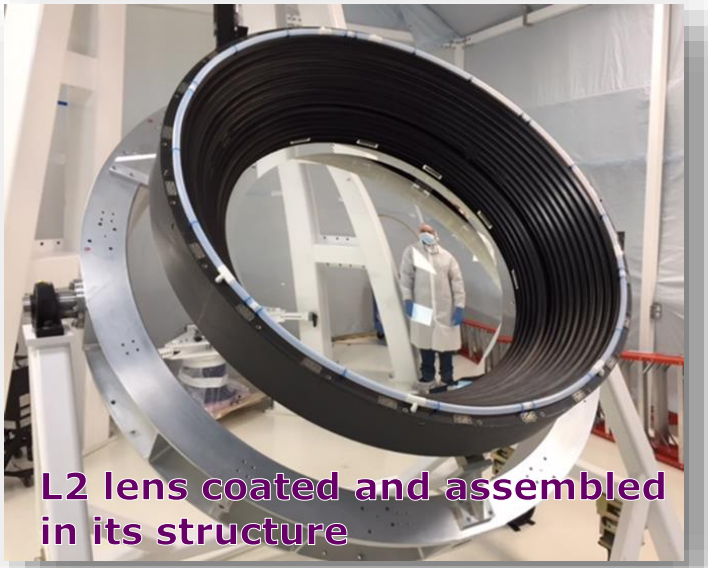
Agency Reviews:

- DOE Review of Facility Operations Dec 2017
- DOE review of DESC Operations Plan May 2018
- NSF/DOE Project Status & Commissioning review Aug 2018
- Planning the next round of reviews

Dark Energy Science Collaboration (DESC):

- Set up to carry out planning and eventual data analysis for DOE HEP science goals
- Data Challenge 2 Run 2.0 production underway on Theta at ANL, Cori at NERSC, and CC-IN2P3
- CosmoDC2 input catalog available for catalog studies

LSST DESC Science Requirement Document (SRD)
https://arxiv.org/abs/1809.01669
Some associated code and data products on public site
https://zenodo.org/record/1409816


L2 lens coated and assembled in its structure


5 mechanical rafts and 2 engineering rafts in the production cryostat

Dark Energy Spectroscopic Instrument (DESI) - Status

DOE-led experiment, mounted and operated on the NSF's Mayall telescope at Kitt Peak.

- "HEP experiment" in the fabrication phase
- Fabricate DESI instrumentation & data management system
  - HEP has MOU w/NSF-AST to "lease" the Mayall telescope; full support for dark energy operations starting FY19

- HEP MIE project funding completes in FY19
- Installation & Commissioning phase has started!

Status:

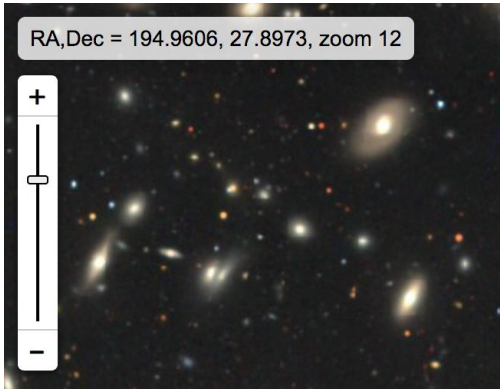
- Project status & Operations plan reviews, Fall 2018
- Full dark energy survey operations starting FY20

Targeting – Legacy Surveys http://legacysurvey.org/

-covering 14000 deg^2 in g,r,z + 4 IR bands

- Mayall z Band Legacy Survey (MzLS) – 100% complete
- Beijing-Arizona Sky Survey (BASS) on Bok – 95%
- DECam Legacy Survey (DECaLS) on Blanco – 90%

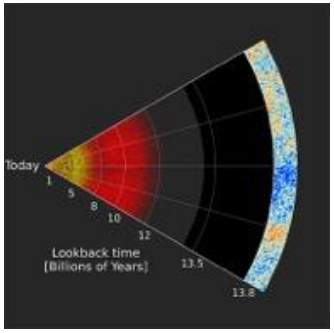
Data Release 7 in July 2018



Dark Energy – Looking to the Future

HEP Cosmic Visions group in Dark Energy (CVDE)

- Allows interactions with small HEP community groups as 2-way line of communication for HEP-funded efforts and directions recommended by P5
- Investigate future HEP directions in the LSST & DESI era
- "Complement, build upon, and extend beyond these experiments in investigating the physics of dark energy."
- White paper on small "enhance" efforts in Feb2018 arXiv:1802.07216
- Any major dark energy experiment will go through Decadal Survey
- Numerous Astro 2020 community white papers expected
- CVDE also helped coordinate community "1 sheet" on Cosmic Acceleration for Congressional visits



TriAgency Group

- DOE/NASA/NSF-AST meetings on Euclid, LSST, WFIRST coordination
- Agency program managers, +Project Leads, +coordinated project task forces
- Annual report from Joint Data Processing task force due in March 2019
- First Joint Cosmological Simulations task force report received in December 2018; agency+project lead review ongoing

Cosmic Frontier: Dark Matter

➔Direct Detection (primary method)

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

- High- and low-mass WIMPs; Axion (meV mass) search

Operating:

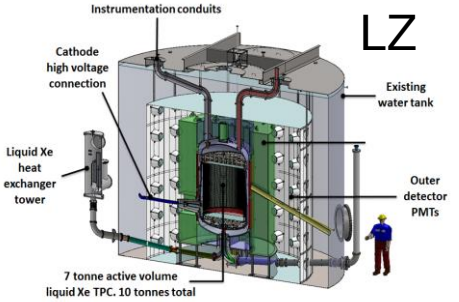
ADMX-G2 axion search at UWash (HEP)

Projects in Fabrication phase:

DM-G2's selected by HEP & NSF-PHY in July 2014 following P5:

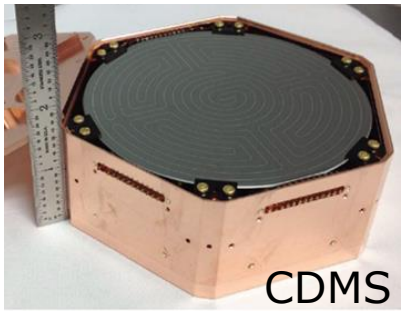
LZ at Homestake Mine in South Dakota (HEP)

- WIMP search through dual phase liquid Xe; ~10-1000 GeV mass range
- In fabrication; planning and funding for operations phase started



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

- WIMP search using cryogenic solid-state crystals; ~1-10 GeV mass
- In fabrication; planning and funding for operations phase started



➔Indirect Detection searches

Gamma-ray & Cosmic ray experiments: Fermi, HAWC, AMS

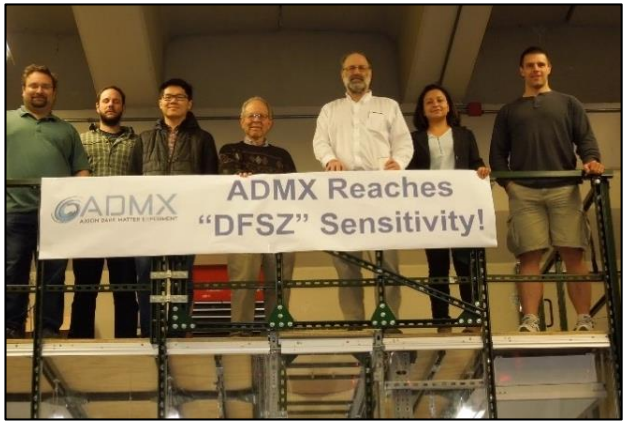
Future Planning: New Initiatives in Dark Matter – small projects

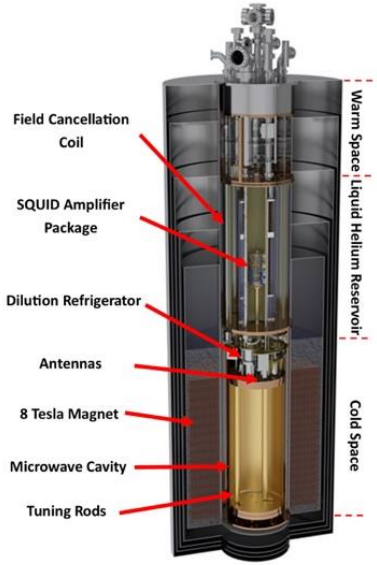
Science Highlight – ADMX-G2

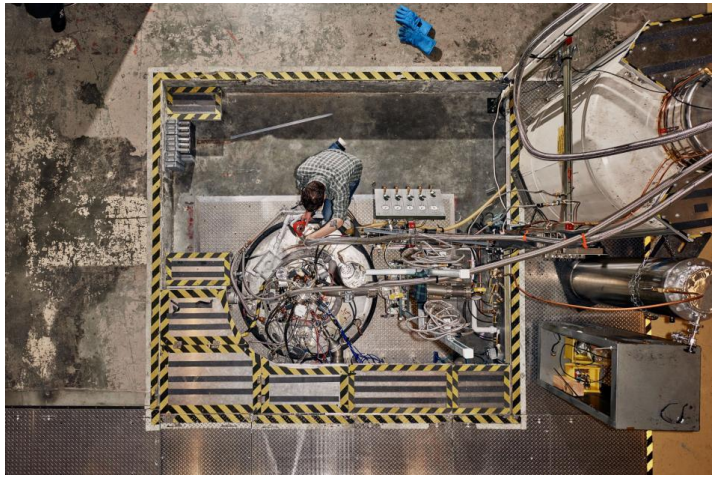
Axion Dark-Matter eXperiment Generation 2

- at Univ of Washington; Managed by Fermilab
- Uses a strong magnetic field and resonant cavity to convert dark matter axions into detectable microwave photons
- Selected as one of three G2 dark matter experiments following P5
  - Currently stepping through range 0.5 to 2 GHz (~ 2 to 8 micro-eV mass)
  - Started operations Aug. 2016; Full data-taking ops run 1A (Jan.-June. 2017)
  - 2nd data run (1B) Feb.- Oct. 2018; 3rd data run (1C) starting early 2019

See recent article in National Geographic:
https://www.nationalgeographic.com/science/2018/10/news-admx-dark-matter-detector-physics/



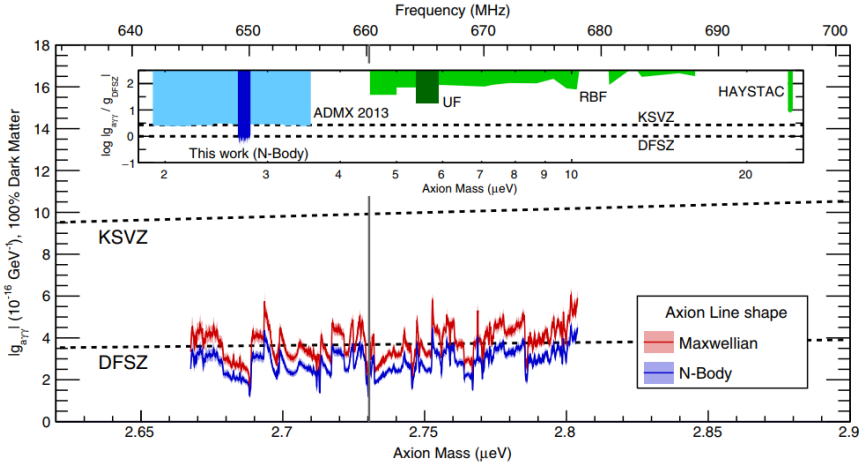




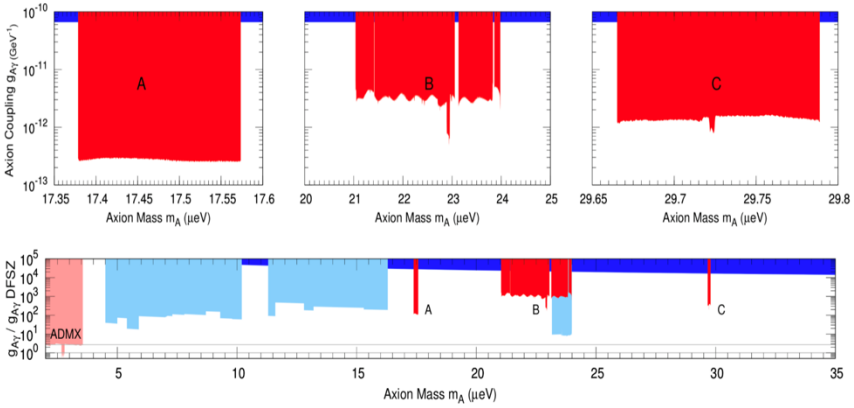
Science Highlight – ADMX-G2

Results:

- May 2017: ADMX reaches DFSZ sensitivity limit at 650 – 680 MHz. First time this limit reach for any axion mass range!
- Published in **Phys. Rev. Lett. 120, 151301 (2018)**
- Published results from Sidecar Cavity: **Phys. Rev. Lett. 121, 261302 (2018)**



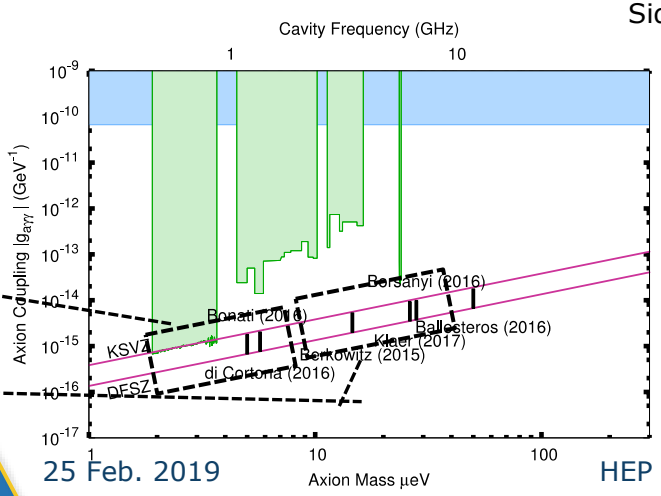
Main ADMX cavity exclusion range



Sidecar multimode cavity exclusion range

ADMX G2 2 GHz
Operations Approved

ADMX G2 10 GHz



Dark Matter QCD Axion "Sweet Spot"

Upper pink line: Optimisitic KSVZ axion coupling

Lower pink line: GUT-inspired DFSZ axion coupling- ADMX G2 target

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

Physics: Direct detection of dark matter particles (WIMPs). Sensitivity to very small energy depositions allows additional searches for axions and lightly ionizing particles (LIP).

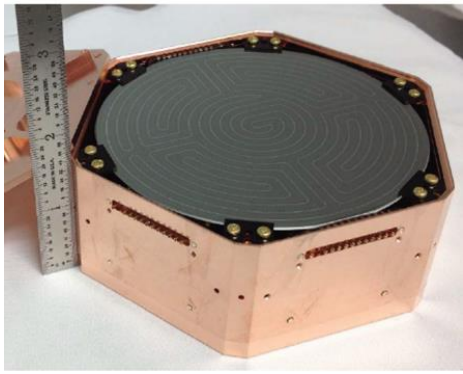
Description: low-mass WIMP experiment; Detector uses cryogenic solid-state germanium and silicon crystals with sensors that detect ionization and phonon signals.

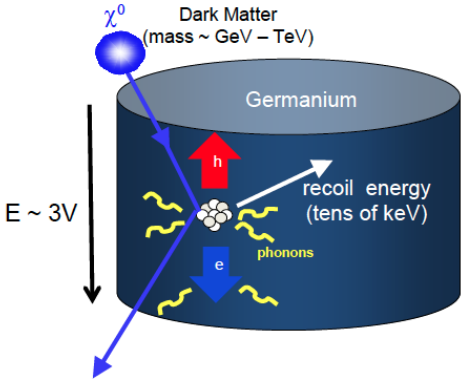
MIE Project, TPC (HEP) $18.6M

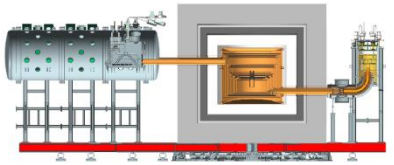
Partnership: DOE and NSF-PHY, contributions from Canada (CFI, NSERC).
Coordination: Joint Oversight Group (JOG) - DOE, NSF, SNOLAB

Status: In fabrication phase - CD-2/3 approved May 2019
Mid-2019 – Installation (staged) starts
Jan. 2020 – Early Project completion
July 2021 – CD4 milestone

Reviews: CD2/3a review Jan. 2018; Preliminary Operations planning review June 2018; next Ops review spring/summer 2019







LUX - ZEPLIN (LZ) Experiment

Physics: Direct detection of WIMPS, dual phase liquid Xe; sensitivity ≤ 2 x 10^{-48} cm^2 , close to where astrophysical neutrinos become an irreducible background.

Description: TPC that uses 7 tons of active liquid xenon to search for xenon nuclei that recoil in response to collisions caused by an impinging flux of dark matter WIMPs. It will be located nearly 1 mile underground in the Sanford Underground Research Facility (SURF) in Lead, South Dakota.

MIE Project: TPC $55.5M (HEP)

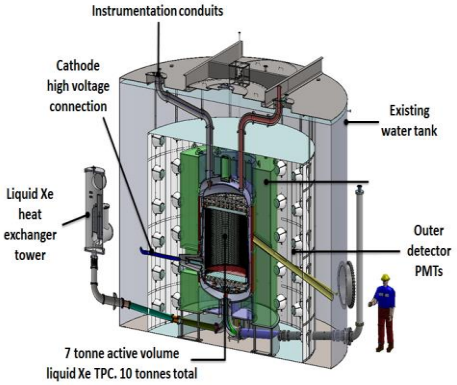
Partnership: HEP experiment (LBNL leads). Has international and private contributions including from UK, Korea, Portugal, SDSTA, Russia

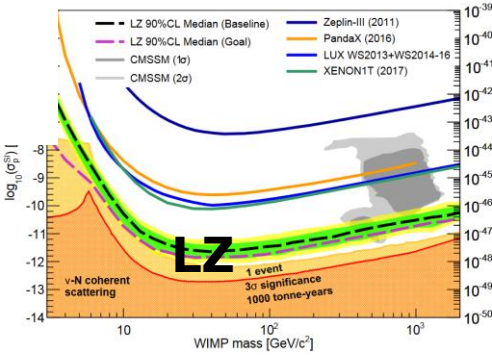
Collaboration: ~200 scientists from 36 institutions in 5 countries

Status: CD3 approved Feb 2017
May 2020 – Early Project completion
March 2022 CD4 planned

Operations Plan: Full 5-year science operations starts ~ July 2020

Reviews: Project Status review Jan 2019: Detailed operations planning review March 2019





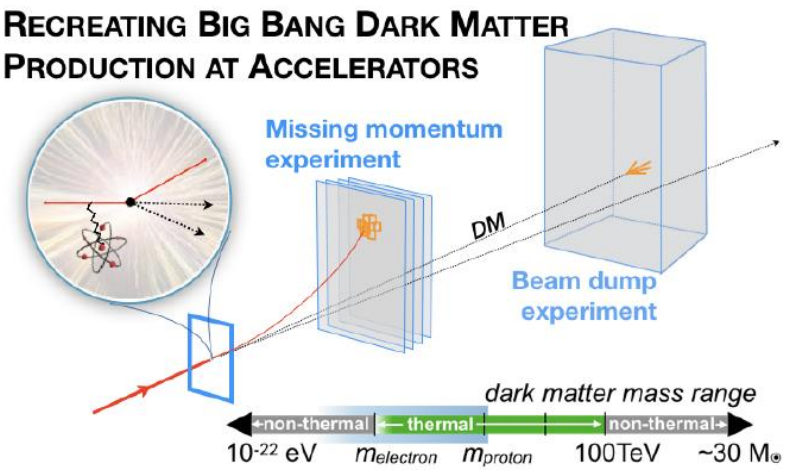
33

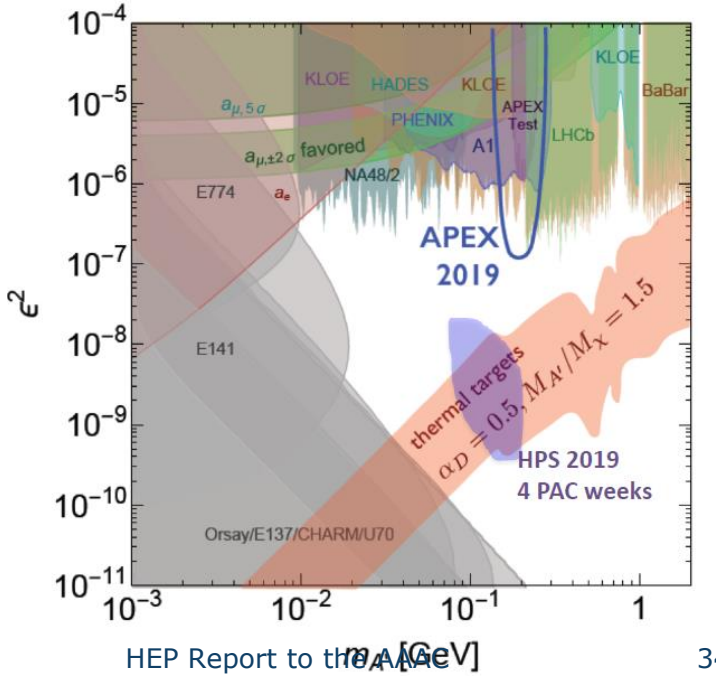
Dark Matter Production and Detection at Accelerators

HEP program also has Accelerator-based Indirect Searches:

- **Energy Frontier:** at the LHC
- **Intensity Frontier**: Fermilab & JLab – using muon beamlines, beam dumps

- The capabilities of DOE accelerators, in particular, multi-GeV CW electron beams and high-intensity proton beams, enable unique opportunities for probing the dark sector. Detector technologies are often synergistic with neutrino experiments.
- In 2018, MiniBooNE-DM (at FNAL) published the results of their search for sub-GeV dark matter produced from collisions of 8-GeV Booster protons at FNAL with a steel beam dump, setting limits on vector portal and leptophobic dark matter models.
- In 2019, both APEX and HPS expect to have physics runs at JLab that will allow them to cover unexplored regions of the A' mass-coupling parameter space.



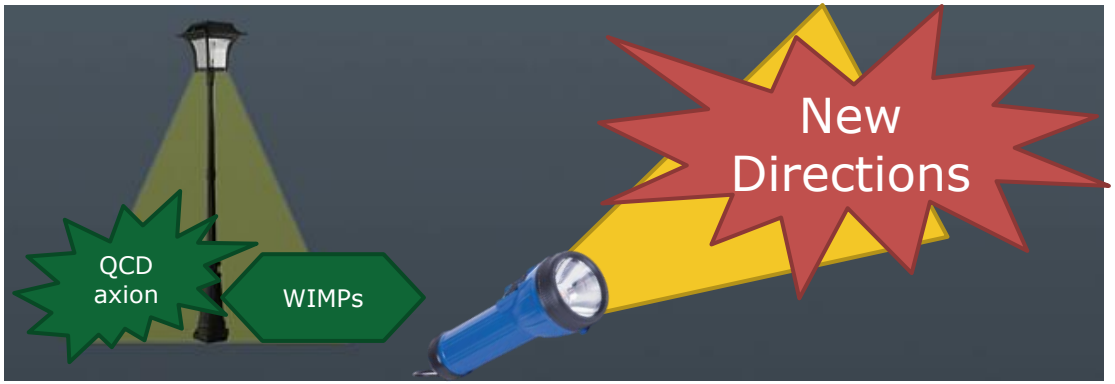


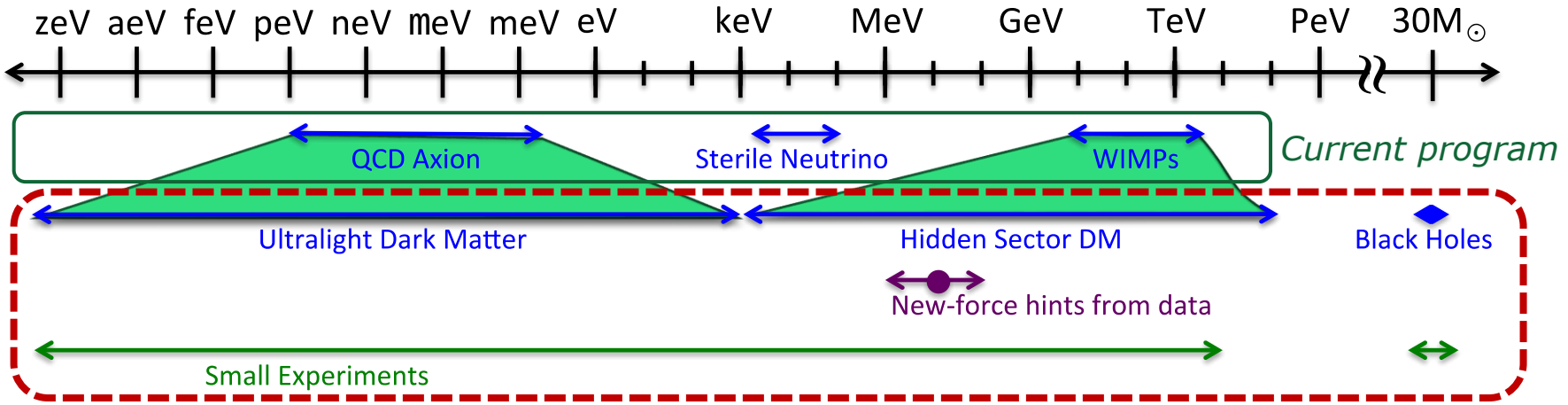
New Opportunities in Dark Matter Science

Recent theoretical studies highlight well-motivated frameworks with sharp, predictive targets from cosmology, fundamental physics, and anomalies in data

- WIMPs, QCD axions central ideas that will be studied with current & planned experiments
- Generalized theories have led to new paradigms that small experiments could address

Technological advances allow new experimental methods





Timeline - New Initiatives in Dark Matter

P5 recommended the search for Dark Matter particles as a high priority & also that the program should include small projects

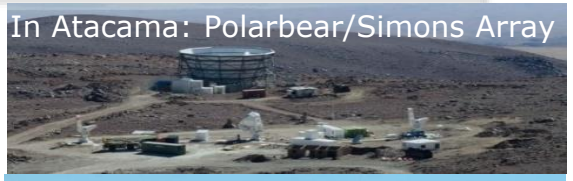
- March 2017: Community-led workshop collected ideas
  - White paper at https://arxiv.org/abs/1707.04591
- **2018: Basic Research Needs (BRN) study for Dark Matter New Initiatives, Chaired by Rocky Kolb & Harry Weerts**
  - Charged to assess the science landscape for dark matter particle searches AND
  - Identify which high impact science areas would be suitable to be pursued with small projects in the HEP program, using DOE lab infrastructure & capabilities
  - Main workshop October 2018; HEPAP Presentation Nov. 2018
  - Brochure & Report - identified 3 priority Physics Research Directions (PRD), see: https://science.energy.gov/hep/community-resources/reports/

Next Steps:

- 2019: Support conceptual development of small experiments/projects
  - Plan to issue FOA in spring 2019 to call for design and near-term technology R&D that respond to high impact PRD opportunities described in the BRN.
- 2020: Select concept(s) for fabrication (possibly in stages)
  - Continue to support theory studies, research efforts, tech. R&D needed to support project(s) as necessary and appropriate

Cosmic Microwave Background

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




South Pole Telescope (SPT) and BICEP/Keck Array

Current Experiments:

- *SPT-3G* – HEP provided support for major upgrade of the camera to greatly increase sensitivity; operations started Feb 2017 (NSF-led)
- HEP is participating in other science collaborations – ground & Planck through NERSC computing

Future Planning – CMB-S4 in P5 plan:

- **DOE should support CMB experiments as a core particle physics program**

-- CMB-S4 intended to be flagship DOE project for Cosmic Frontier last half 2020s

- **Multidisciplinary nature of the science warrants multi-agency support**
  - NSF astronomy & DOE particle physics communities
  - DOE lab tech capability for detector fab, DAQ, HPC

Science Highlight: SPT-3G

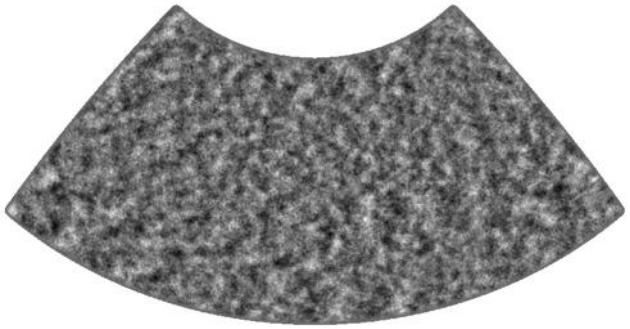
Third-generation Receiver for the South Pole Telescope

DOE-HEP partnership with NSF-OPP lead and NSF-PHY, NSF-AST

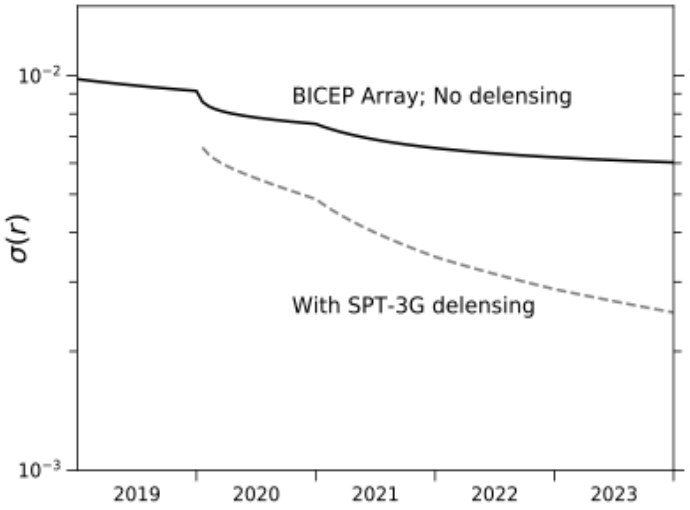
- HEP provided support for fabrication of 16,000-detector SPT-3G focal plane at ANL and provides partial support of operations

1500-square-degree survey is **underway**.

- Currently preparing publication of 2018 data—will represent best constraint on TE/EE power spectra in multipole range 1000 <~ l <~ 2000.
- Final 5-year data set will be unprecedentedly deep at arcminute angular scales: projected map noise of 2.2 uK-arcmin at 150 GHz (3.0 and 8.8 at 90 and 220 GHz). Will enable groundbreaking results, including constraints on Dark Energy and Modified Gravity from CMB lensing and the Sunyaev-Zel'dovich effects, constraints on the properties of neutrinos and other light particles, and, together with BICEP/Keck, a potential detection of primordial gravitational waves.
- Together with deep degree-angular-scale data from the BICEP/Keck program, de-lensing enabled by the high-resolution SPT-3G data will achieve limit on the tensor-to-scalar ratio r of sigma(r) ~ 0.0025. Without the SPT-3G data, the r limit would be limited by lensing at over a factor of two higher.



1500 deg^2 SPT-3G field



Stage 4 Cosmic Microwave Background, CMB-S4

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

-Notional array of several telescopes in Chile & South Pole with ~ 0.5 M detectors

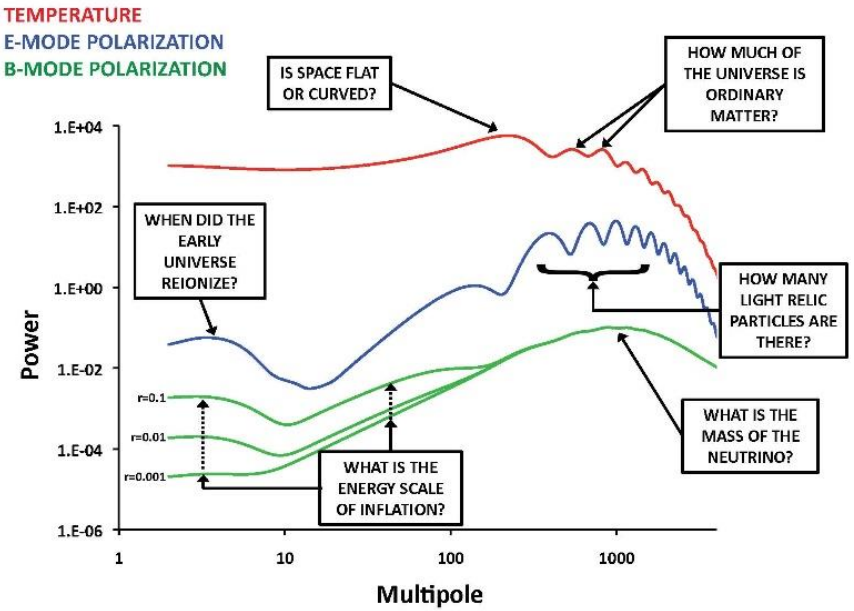
-Needs scale-up of detector fabrication, testing, and readout

CMB-S4 Collaboration Science, Technology Books:

https://arxiv.org/abs/1610.02743 ; https://arxiv.org/abs/1706.02464

AAAC charged Concept Definition Task Force (CDT) with science requirements & conceptual strawperson design/cost/schedule – approved Fall 2017

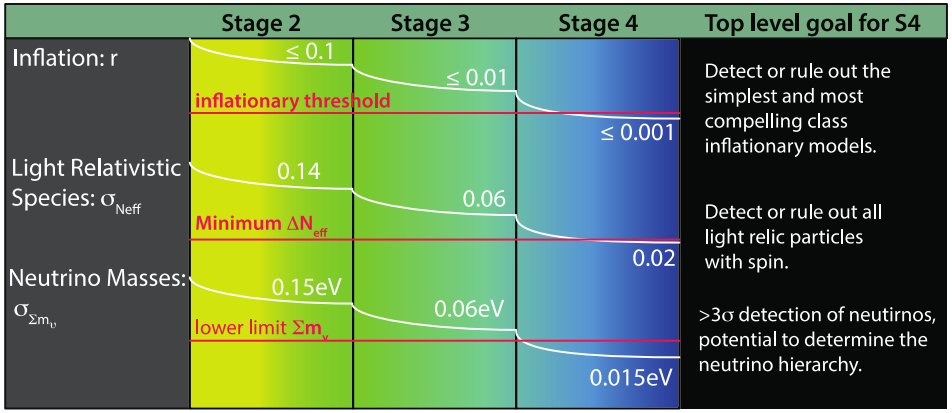
- Sites at South Pole and Chile
- Large and Small aperture telescope deployment and throughput
  - 3 large aperture telescopes of 6m diameter,
  - 14 small aperture cameras of 0.5m diameter
- 9 frequency bands from 20 – 220 GHz

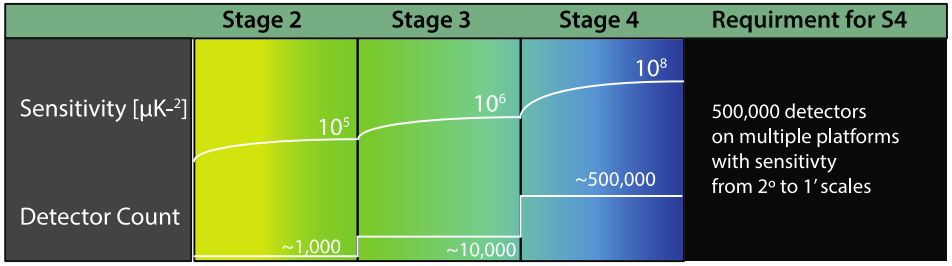


Stage 4 Cosmic Microwave Background, CMB-S4

Science: Community driven experiment - science drivers include:

- B-mode polarization search for primordial gravitational waves, inflation
- Light relics particles; neutrino mass scale
- Dark Energy test through growth of structure, CMB-Lensing cross-correlation with galaxy density and shear surveys, e.g., LSST.
- Baryonic Feedback constraints on galaxy Formation and evolution





20 Decadal Survey science white papers being drafted.

Collaboration formalized Spring 2018

- Co-Spokespersons Julian Borrill & John Carlstrom
- 184 members and growing; 138 US + Australia, Canada, France, Germany, Italy, Japan, Sweden, Taiwan, UK
- Frequent collaboration meetings → next one March 12-15


CMB-S4 Workshop at Princeton, Fall 2018

CMB-S4 - pPDG & Collaboration planning

Following the CDT report, DOE labs established **pre-Project Design Group (pPDG) in coordination with Collaboration**

1. Develop & refine project plan based on strawman design
2. Synchronize agency and panel processes: Decadal Survey, DOE CD0/CD1…, NSF PDR/FDR MREFC…
3. Will be the POC on DOE R&D and concept planning towards CMB-S4 CD-1
4. DOE+NSF agree on Jim Yeck as pPDG lead (project manager experience from LHC, IceCube, LBNF, ESS)

<u>pPDG planning</u>

Building on CDT strawman concept definition, Collaboration and preProject Development Group (pPDG) developing technically driven project plan

- includes full CATEable schedule, management plan, bottoms up costing, and with proposed NSF and DOE roles and responsibilities defined.
- **basis for documentation for Decadal Survey and to advance through DOE CD and NSF phases.**
- full report will include Science, Science flow down to measurements, reference design and project plan.
- held review of the DSR Dec 11 – 13, 2018, co-chaired by Mark Reichanadter and Steve Ritz.

CMB-S4 – Agency Planning & Coordination

DOE Planning

- Supportive of the Team's plan & working towards supporting pPDG and Collaboration's schedule
- DOE provided $1.5M FY18 R&D funding, went through pPDG to design/engineering (+LDRD+Research); FY19 amount still in discussion

DOE HEP planning CD0, start of project process, in spring 2019

DOE and NSF coordination:

NSF/DOE Joint Coordination Group meets biweekly/monthly

- Agencies, pPDG, spokespeople in close communication
- Will work to enable synchronization of DOE and NSF timescales & processes

Exploring the Unknown

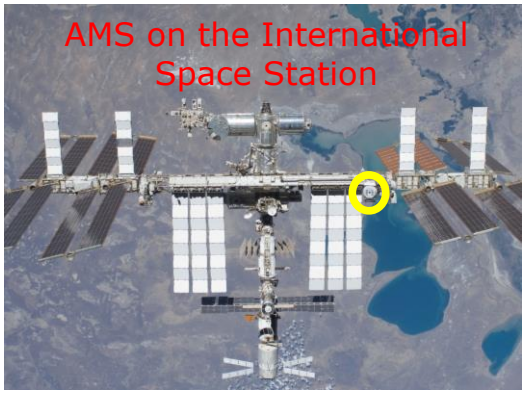
Use ground-based arrays, space telescopes, and an experiment on the International Space Station to explore the unknown, e.g. indirect searches for dark matter

Many significant inter-agency & international partnerships

Operations continuing:

Fermi/GLAST (w/NASA)

- 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 for operations past 10 years



AMS (w/NASA)

- Operations continuing on ISS

HAWC (w/NSF)

- 5 year operations started early 2015

Lower program priority for new cosmic-ray, gamma-ray experiments

ASTRO 2020 Decadal Survey - HEP

DOE, NASA, NSF worked together to deliver a statement of task to the National Academy of Sciences for an Astronomy & Astrophysics Decadal Survey (Astro 2020).

→DOE-HEP continues to support detector development & experiment concept development for the future.

→Community has been actively planning:

CMB – CMB-S4 will be proposed to Astro 2020 for partnership of DOE-HEP, NSF-AST/PHY/OPP

Dark Energy – science ideas for enhancing and going beyond DESI and LSST will be proposed to Astro 2020; small, medium, large scale project ideas

Dark Matter Direct Detection – excluded in SOT due to purview of HEP/Particle Physics community; fully informed by HEPAP/P5

Exploring the Unknown – always interested in exciting new physics idea central to DOE mission

Cosmic Frontier Experiments

Activity	Location	Science	Current Status	# Collaborators	# Institutions	# Countries
Extended Baryon Oscillation Spectrosopic Survey (BOSS)	APO in New Mexico	dark energy stage III (spectroscopic)	operations started 2015	100 (60 US, 40 HEP)	34 (22 US, 10 HEP)	10
Dark Energy Survey (DES)	CTIO in Chile	dark energy stage III (imaging)	operations started Sep 2013	500	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	269 (195 US, 47 HEP)	63 (43 US, 22 HEP)	15
Large Synoptic Survey Telescope (LSST) - LSSTcam Project	Cerro Pachon in Chile	dark energy stage IV (imaging)	FY14 fab start; CD3 Aug 2015	142 (111 US, 111 HEP)	17 (11 US, 11 HEP)	2
Dark Energy Spectroscopic Instrument (DESI)	KPNO in AZ	dark energy stage IV (spectroscopic)	FY15 fab start; CD3 June 2016	200 (93 US, 74 HEP)	55 (21 US, 19 HEP)	9
DM-G1: Large Underground Xenon (LUX)	SURF in South Dakota	dark matter - WIMP search	Operations ended in 2016	102 (86 US, 64 HEP)	18 (15 US, 13 HEP)	3
DM-G1: Super Cryogenic Dark Matter Search (SuperCDMS-Soudan)	Soudan in Minnesota	dark matter - WIMP search	Operations ended in 2016	83 (72 US, 44 HEP)	20 (17 US, 7 HEP)	3
DM-G2: ADMX-G2	Univ Washington	dark matter - axion search	Operations started Jan. 2017	23 (21 US, 18HEP)	8 (7 US, 4 HEP)	2
DM-G2: SuperCDMS-SNOLAB	SNOLab in Canada	dark matter - WIMP search	FY15 fab start; CD3 May 2018	109 (86 US, 57 HEP)	22 (16 US, 7 HEP)	5
DM-G2: LZ	SURF in South Dakota	dark matter - WIMP search	FY15 fab start; CD3 Feb. 2017	252 (174 US, 161 HEP)	38 (26 US, 23 HEP)	5
SPT-3G	South Pole	CMB stage 3	Operations started Feb. 2017	59	9 (7 US,5 HEP)	3
Very Energetic Radiation Imaging Telescope Array System (VERITAS)	FLWO in AZ	gamma-ray survey	HEP ops completed 2016	109 (76 US, 28 HEP)	20 (16 US, 5 HEP)	4
Pierre Auger Observatory	Argentina	cosmic-ray	HEP ops completed 2016	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	252 (104 US, 18 HEP)	109 (37 US, 3 HEP)	22
Alpha Magnetic Spectrometer (AMS-02)	space-based (on ISS)	cosmic-ray	May 2011 launch; operating	250	46 (6 US, 2 HEP)	16
High Altitude Water Cherenkov (HAWC)	Mexico	gamma-ray survey	Operations started Jan. 2015	120 (60 US, 7 HEP)	30 (13 US, 3 HEP)	4

DOE Cosmic Frontier Conclusion

Cosmic Frontier is churning out world-leading science results!

4 MIE Projects are coming to fruition

CMB-S4 planning ramping up

Experiments at all stages of lifecycle:
Concept, design, construction, commissioning, data!

Astro 2020 Decadal Survey starting up

U.S. DEPARTMENT OF
ENERGY | Office of Science

Funding Opportunities

HEP Funding Opportunity Announcements (FOA)

See **https://www.science.energy.gov/hep/funding-opportunities/**

FOAs released

FY19 National Lab Program Announcement (NLA): *"US-Japan Science and Technology Cooperation Program in High Energy Physics"* [LAB 19-1902], for the FY 2019 US-Japan cooperative R&D program

- issued October 15, 2018; proposals were due December 14, 2018

FY19 Research Opportunities in High Energy Physics ("Comparative Review"): Main funding source for university grants

- **issued November 5, 2018; proposals were due January 22, 2019**

2019 Research Opportunities in Accelerator Stewardship

- Supports basic accelerator research of broad benefit; conducted with 11 federal agencies
- Proposals due April 23, 2019

2019: Quantum Information Science Enabled Discover

- Proposals due April 16, 2019

Note: DOE Labs are funded via a separate Field Work Proposal process & review.

FOAs in planning

2019 DOE Traineeship in Accelerator Science & Engineering

- Student support; Planned for release early in 2019

2019: Dark Matter New Initiatives

- **Project design & near-term tech R&D aligned w/Physics Research Directions in the BRN report**
- **Planned for release in spring 2019**

SC-wide Funding Opportunity Announcements (FOA)

Early Career Research: https://science.energy.gov/early-career/ for Labs & Universities

- ***FY19 "Early Career Research Program"***
  - issued January 7, 2019; Pre-proposals (required) due Feb. 6, 2019; Proposals due April 29, 2019

SC General" FOA (typically a new FOA annually; "always open")

- HEP uses this primarily for conferences and unforeseen circumstances (e.g. supplements)

Science Undergraduate Laboratory Internships (SULI); Applications due January 10, 2019

Community College Internships (CCI); Applications due January 10, 2019

Visiting Faculty Program (VFP); Applications due January 10, 2019

Office of Science Graduate Student Research Program (SCGSR)

- Two annual solicitations in May and November; Most recent solicitation included 15 applications for HEP

Albert Einstein Distinguished Educator Fellowship; Annual cycle closed November 15, 2018

U.S. DEPARTMENT OF ENERGY | Office of Science

Important Notes

Diversity and Inclusion

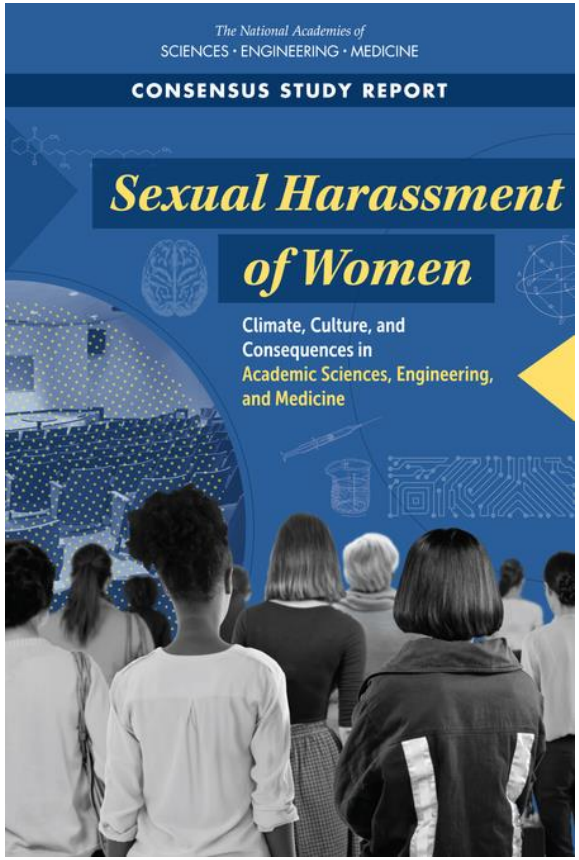
- The **2016 HEP Committee of Visitors** recommended that HEP **"develop a plan for increasing diversity in the programs HEP supports."**
- HEP is working with **Office of Science** management to develop strategies for improving diversity in its research programs
  - HEP is participating in a new SC-wide diversity and inclusion working group that aims to establish shared **best practices across program offices**
  - HEP works with the **DOE National Laboratories** to monitor and encourage diversity and inclusion efforts through its contracts, annual planning processes, and budget briefings
  - HEP participates in **Workforce Development for Teachers and Scientists** programs
    - WDTS supports >1,000 students and faculty annually
- The 2015 GAO report on Women in STEM Research and the 2016 HEP COV recommended that HEP **collect further demographic data** for grant applicants:
  - HEP should **work with the Office of Science to obtain demographic information**, including information at the proposal stage. Inadequate demographic information is available to assess the success rate of different populations that apply for funding by HEP.
  - Implicit bias in reviews is a concern, but conclusions cannot be drawn without data. **Improved demographic information would facilitate tracking of progress in achieving diversity** in particle physics
  - **Grant applicants and contributors can voluntarily supply information in PAMS**

Sexual Harassment Issues

"[S]exual harassment is a serious issue for women at all levels in academic science, engineering, and medicine, and that these fields share characteristics that create conditions that make harassment more likely to occur. **Such environments can silence and limit the career opportunities** in the short and long terms for both the targets of the sexual harassment and the bystanders—with at least some leaving their field. The consequence of this is a significant and costly loss of talent in science, engineering, and medicine.

However, we are encouraged by the **research that suggests that the most potent predictor of sexual harassment is organizational climate**—the degree to which those in the organization perceive that sexual harassment is or is not tolerated. This means that **institutions can take concrete steps to reduce sexual harassment** by making system-wide changes that demonstrate how seriously they take this issue and that reflect that they are listening to those who courageously speak up to report their sexual harassment experiences."

- The National Academies of Science, Engineering, and Medicine, 2018



http://sites.nationalacademies.org/shstudy/index.htm

Dr. Frazier Benya, an editor of this report, spoke at the November HEPAP meeting

Expectations for Professional Behavior

- The Office of Science is exploring the development of an official statement regarding expectations for how individuals it interacts with should conduct themselves
- In the interim, The Office of High Energy Physics embraces the Code of Conduct adopted by the American Physical Society, and it will remind attendees at meetings it convenes, including review panels, site visits, etc., that it expects a standard for professional behavior that is consistent with the APS declaration.

The APS Code of Conduct

It is the policy of the American Physical Society (APS) that all participants, including attendees, vendors, APS staff, volunteers, and all other stakeholders at APS meetings will conduct themselves in a professional manner that is welcoming to all participants and free from any form of discrimination, harassment, or retaliation. Participants will treat each other with respect and consideration to create a collegial, inclusive, and professional environment at APS Meetings. Creating a supportive environment to enable scientific discourse at APS meetings is the responsibility of all participants.

Participants will avoid any inappropriate actions or statements based on individual characteristics such as age, race, ethnicity, sexual orientation, gender identity, gender expression, marital status, nationality, political affiliation, ability status, educational background, or any other characteristic protected by law. Disruptive or harassing behavior of any kind will not be tolerated. Harassment includes but is not limited to inappropriate or intimidating behavior and language, unwelcome jokes or comments, unwanted touching or attention, offensive images, photography without permission, and stalking.

U.S. DEPARTMENT OF
ENERGY | Office of Science

Closing Remarks

Timeline for Updating the U.S. 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
  - 2013-2014 HEPAP P5 subpanel
- The timeline of processes that impact strategic planning is:
  - 2018: Anticipated Japanese decision on ILC
  - 2018-early 2021: New NAS Astronomy and Astrophysics Decadal Survey
  - 2019-2020: European Strategy for Particle Physics process
  - 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 next P5 recommendations in time to inform the FY 2024/25 budget
- **U.S. community encouraged to work with US and international collaborators in developing other regional plans with a global vision for particle physics**

Closing Remarks

- **Excellent science results continue to be produced from our operating experiments!**
- **Broad support is enabling us to implement the P5 strategic plan and achieve its vision**
  - Thanks to DOE Management, Administration, & Congress for support
  - SC programs in QIS, computing, and SLI provide additional support to enable P5
  - **Community continues to be unified in support of P5 strategy**
- **The FY 2019 appropriation will enable continued P5 progress**
  - Maintaining a healthy research budget is an ongoing challenge
- **The particle physics community continues to perform well on delivering projects, a foundation of the long-term strategy**

U.S. DEPARTMENT OF
ENERGY

Office of
Science