



U.S. DEPARTMENT OF
ENERGY

Office of
Science

Cosmic Frontier

Astronomy & Astrophysics Advisory Committee

21 Sep 2020

*Drew Baden, Karen Byrum, Eric Linder, **Kathy Turner***

*Experimental Research at the Cosmic Frontier
Office of High Energy Physics*

Cosmic Frontier Experimental Research Program

- ▶ What is the DOE-HEP Cosmic Frontier?
- ▶ HEP Program Planning and Budgets
- ▶ Cosmic Frontier Program Overview, Status
- ▶ Diversity, Equity, Inclusion
- ▶ Response to AAAC Report Recommendations














Cosmic Frontier Experimental Research Program

→ Cosmic Frontier Experimental researchers use naturally occurring cosmic particles and phenomena to reveal the nature of dark energy and dark matter, comprising ~95% of the universe, understand the cosmic acceleration caused by dark energy and inflation, infer neutrino properties, and explore the unknown.

Program Areas:

- Study the nature of Dark Energy using imaging & spectroscopic surveys
- Direct Detection searches for Dark Matter particles
- CMB – Inflationary Epoch, Dark Energy, Neutrino Properties

Particle Physics Science Drivers	Research Frontiers			
		Energy Frontier	Intensity Frontier	Cosmic Frontier
	Higgs Boson			
	Neutrino Mass			
	Dark Matter			
	Cosmic Acceleration			
	Explore the Unknown			

Always interested in Exploring the Unknown and New Physics!



Mission of the DOE Office of Science

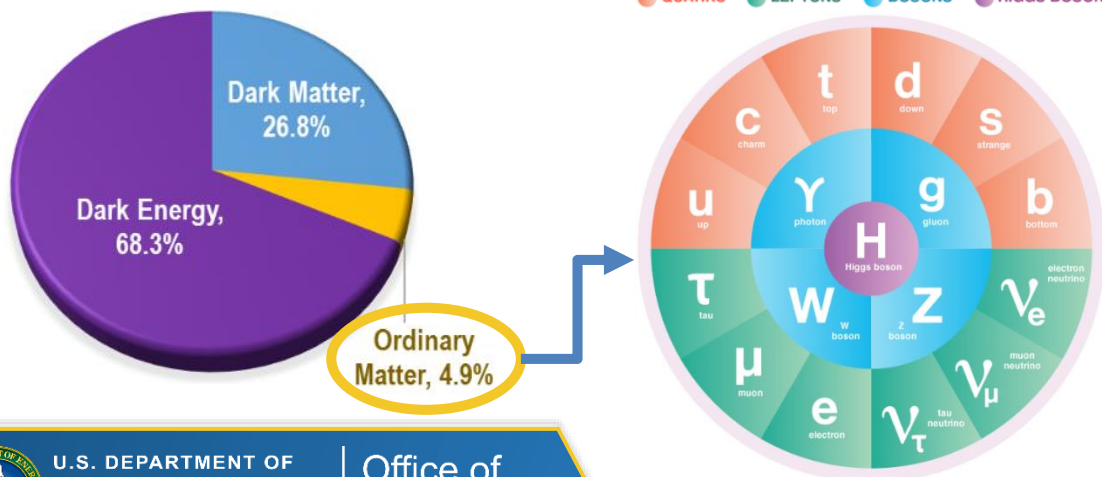
- The Office of Science Mission is to deliver the scientific discoveries and major scientific tools that transform our understanding of nature and advance the energy, economic, and national security of the United States



Office of High Energy Physics (HEP) 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

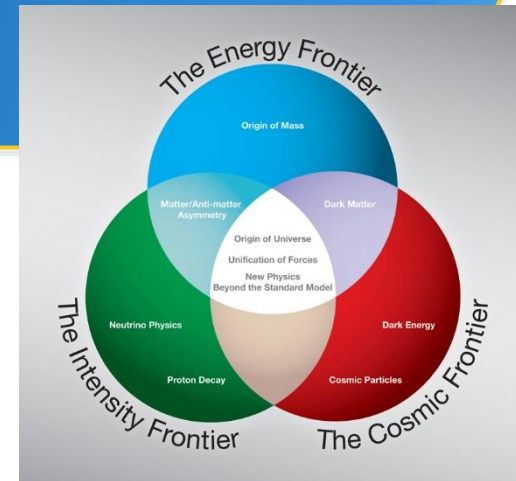


HEP Program Layout

HEP is carried out along 3 Frontiers:

Advancements at all 3 frontiers are needed to achieve the long term goals of the field.

→HEP is primarily a Particle Accelerator based program: **Energy & Intensity Frontiers**



→**Cosmic Frontier is an increasingly important area for discovery.** Experiments use naturally occurring data to provide additional input to the Standard Model picture: Cosmic Acceleration (Dark Energy, Inflation), search for Dark Matter particles, New Physics (neutrino properties, relic particles, etc)

Crosscutting HEP subprograms:

- ▶ Theoretical research, High Performance Computing & Computational HEP, Advanced Detector R&D, Quantum Information Science (QIS).



HEP Program Execution

DOE is a mission-oriented agency. The **projects** are selected for the (P5) strategic plan that will provide significant leaps in science. Then we **support the community to carry out** these projects/experiments.

- The priority is to support efforts directly in line with HEP program & project priorities, responsibilities & science goals, including research.

DOE/HEP is not a unique supporter of Cosmic Frontier research goals; but HEP research community does bring some particular scientific expertise and technical resources

→ **2009 HEPAP/PASAG report criteria** guides determination of the scope and funding level for HEP participation in specific projects.

- For projects that make significant leaps in addressing HEP goals, we consider unique/leadership participation and contributions that makes use of our expertise and capabilities

Particle Physics is Global

- Form partnerships or use other agency's/country's facilities when needed
- Most HEP projects have international contributions and/or partners
- Many HEP projects have significant planning & coordination with offices in other agencies: NSF-PHY, NSF-AST, NSF-OPP, NASA



HEP Program Guidance

FACA panels & subpanels provide official advice:

- ▶ High Energy Physics Advisory Panel (HEPAP)
 - ▶ Jointly chartered by DOE and NSF to advise both agencies
 - ▶ **Provides the primary advice for the program**
 - ▶ Subpanels for detailed studies (e.g. **Particle Physics Project Prioritization Panel ("P5")**) in 2008, 2014, 2021
- ▶ Astronomy and Astrophysics Advisory Committee (AAAC)
 - ▶ Advises DOE, NASA, NSF on selected issues in astronomy & astrophysics of overlap, mutual interest and concern – **many experiments in partnership**

Formal Advice Also Provided by:

- ▶ National Academy of Sciences (NAS)
 - ▶ Decadal Surveys in Astronomy & Astrophysics, in Elementary Particle Physics
 - ▶ Board on Physics & Astronomy (BPA), Committee on Astronomy & Astrophysics (CAA)

Other:

- ▶ Community science studies and input; Cosmic Visions groups; Basic Research Needs groups
- ▶ AAAC subpanels, e.g. CMB-S4 Concept Definition Taskforce (CDT), Gemini-Blanco-SOAR Telescopes roles
- ▶ Astro-Particle International Forum (APIF) – Agency-level international group
- ▶ Tri-Agency Group (TAG) – DOE, NASA, NSF-AST meetings on Rubin (LSST), Roman (WFIRST), Euclid coordination



HEP – follows P5 Strategic Plan

HEP science priorities come from community via HEPAP advisory panel **Particle Physics Project Prioritization Panel (“P5”)** strategic plan. The 2014 report:

- provided the critical scientific questions
- recommended a portfolio of facilities and projects in Energy, Intensity, Cosmic Frontiers to optimally address the science within realistic constraints; also investments in Theory, Detector R&D, Accelerator R&D
- 10 year plan, with 20 year vision

P5 recommended **Cosmic Frontier** science & project priorities in Dark Energy, Dark Matter (direct detection), and CMB

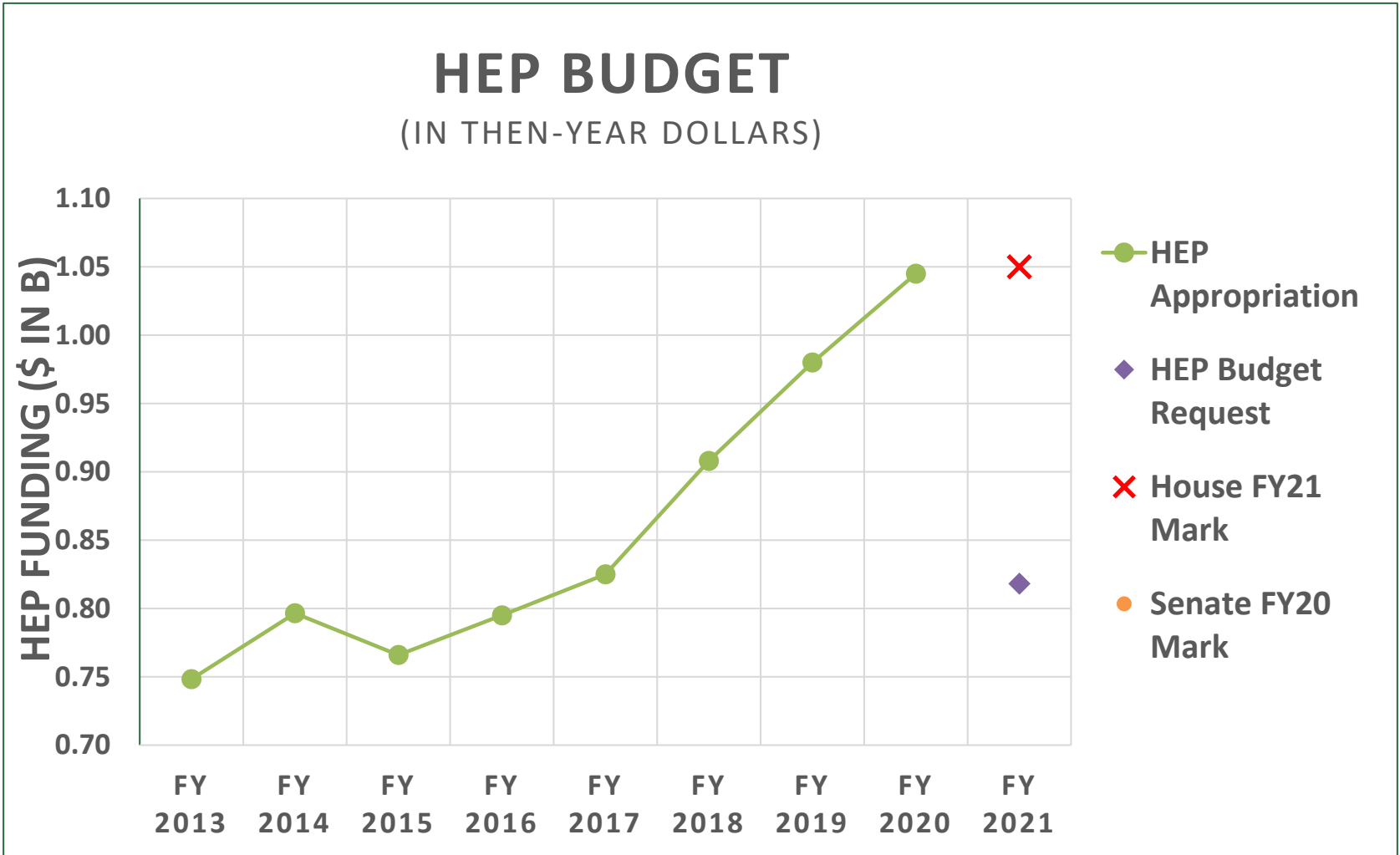
- **Dark Energy:** build LSST (Rubin) & DESI
- **Dark Matter:** suite of “generation 2” direct detection experiments
- **CMB:** support as part of the core program within multi-agency context; carry out multi-agency CMB-S4 project later in the decade
- Maintain a portfolio of **small projects:** e.g. ADMX-G2, SPT-3G, Dark Matter New Initiatives

HEP Community support of this process is a critical element of its success



U.S. Congress Supports P5 Strategy

U.S. Congress continues to show strong support for executing the P5 strategy



FY 2021 President's Request Budget for DOE Office of Science

SCIENCE

(dollars in thousands)

	FY 2019 Enacted	FY 2020 Enacted	FY 2021 President's Request	FY 2021 Request vs. FY 2020 Enacted	
				\$	%
Office of Science					
Advanced Scientific Computing Research	935,500	980,000	988,051	+8,051	+0.8%
Basic Energy Sciences	2,166,000	2,213,000	1,935,673	-277,327	-12.5%
Biological and Environmental Research	705,000	750,000	516,934	-233,066	-31.1%
Fusion Energy Sciences	564,000	671,000	425,151	-245,849	-36.6%
High Energy Physics	980,000	1,045,000	818,131	-226,869	-21.7%
Nuclear Physics	690,000	713,000	653,327	-59,673	-8.4%
Workforce Development for Teachers and Scientists	22,500	28,000	20,500	-7,500	-26.8%
Science Laboratories Infrastructure	232,890	301,000	174,110	-126,890	-42.2%
Safeguards and Security	106,110	112,700	115,623	+2,923	+2.6%
Program Direction	183,000	186,300	190,306	+4,006	+2.2%
Total, Office of Science	6,585,000	7,000,000	5,837,806	-1,162,194	-16.6%

The SC Request includes ongoing investments to support the Administrations Industries of the Future (IOTF) initiative through research in **quantum information sciences (QIS)** and **artificial intelligence (AI) and machine learning (ML)**. The Request also supports research efforts in next-generation **microelectronics**, genomic sciences to inform biosecurity research, and critical scientific infrastructure needs at DOE laboratories. The Request also initiates several new multidisciplinary research initiatives including: data and computational collaboration with NIH, integrated computational and data infrastructure for scientific discovery, next generation biology, rare earth and separation science, revolutionizing polymer upcycling, and **strategic accelerator technology**. These new initiatives position SC to meet new research demands in an enhanced collaborative effort.



FY 2021 HEP Budget Request

HEP Funding Category (\$ in K)	FY 2019 Actual	FY 2020 Enacted	FY 2021 Request	FY 2021 vs. FY 2020
Research	372,629	390,077	328,903	-61,171
Facilities/Operations	266,556	316,429	285,725	-30,704
Projects	340,815	338,494	203,500	-134,994
Total	980,000	1,045,000	818,131	-226,869

FY 2021 President's Budget Request is overlay of Administration, SC, P5 priorities

- SC: interagency partnerships, national laboratories, accelerator R&D, QIS, AI/ML
- HEP: continue successful P5 execution, advance Administration and DOE/SC initiatives

FY 2021 HEP Budget continues support for P5-guided investments

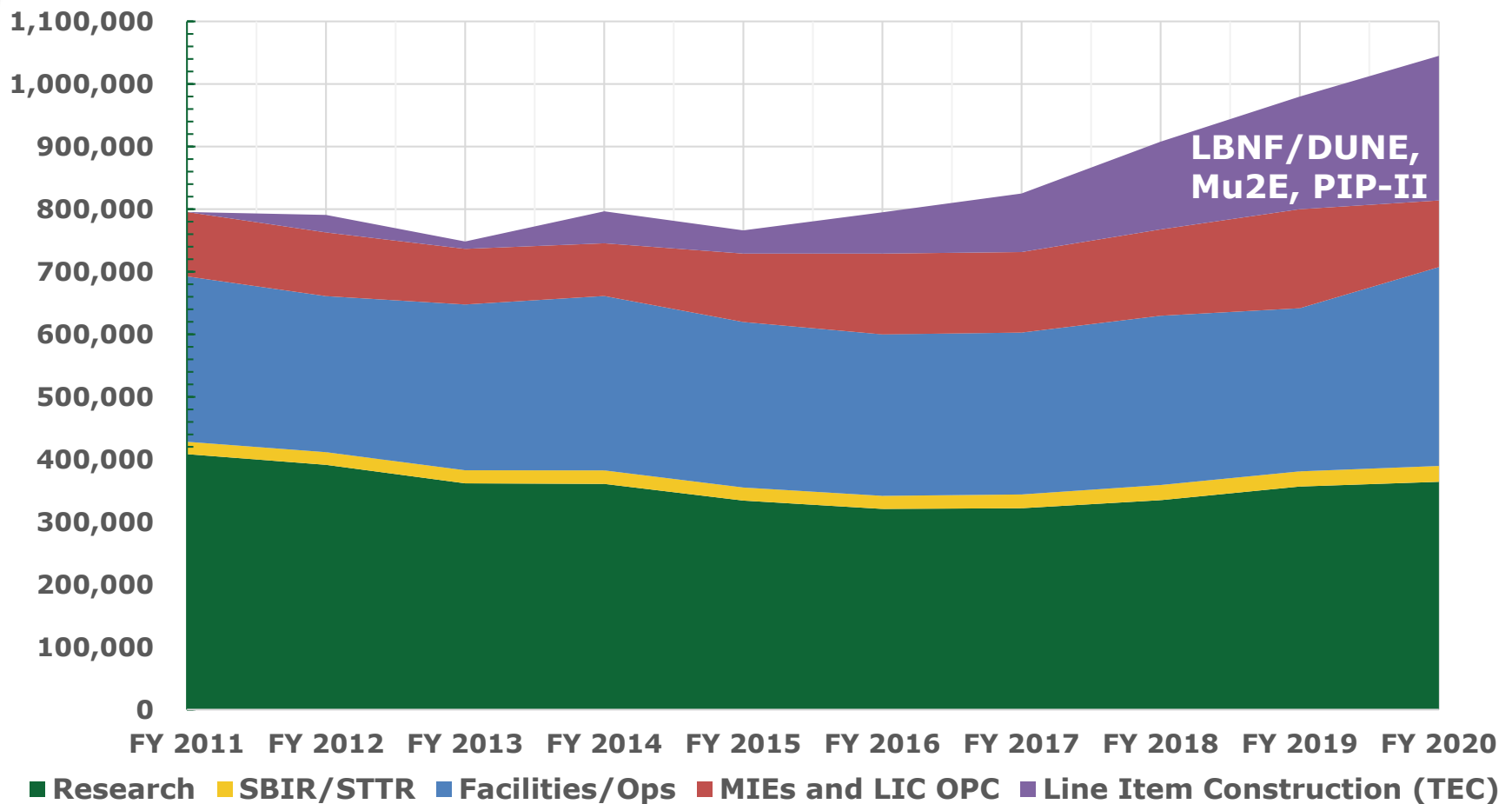
- Research: Continue U.S. leadership in LHC, muon experiments, international neutrino experiments at Fermilab, dark matter, dark energy, and vibrant theory program; QIS; AI/ML; Microelectronics centers (with ASCR, BES, and FES); Strategic Accelerator Technology Initiative; Traineeships in accelerator science
- Operations: Support HEP user facilities and running P5-recommended experiments
- Line Item Construction and Projects: HL-LHC Accelerator and ATLAS & CMS Detectors, LBNF/DUNE, PIP-II, **new MIE start for CMB-S4**

FY 2021 House Mark: \$1.050B for HEP. Additional infrastructure package under House consideration.



HEP Budget (\$k) FY 2011-2020

Research, Operations, Projects: (Construction and MIEs)



HEP Budget Challenges: Much of the growth has been in Projects without needed increases in Research and Operations for which HEP-style project rely heavily. Efforts by various community-led forums to communicate the message that healthy growth of the program requires support in all areas.



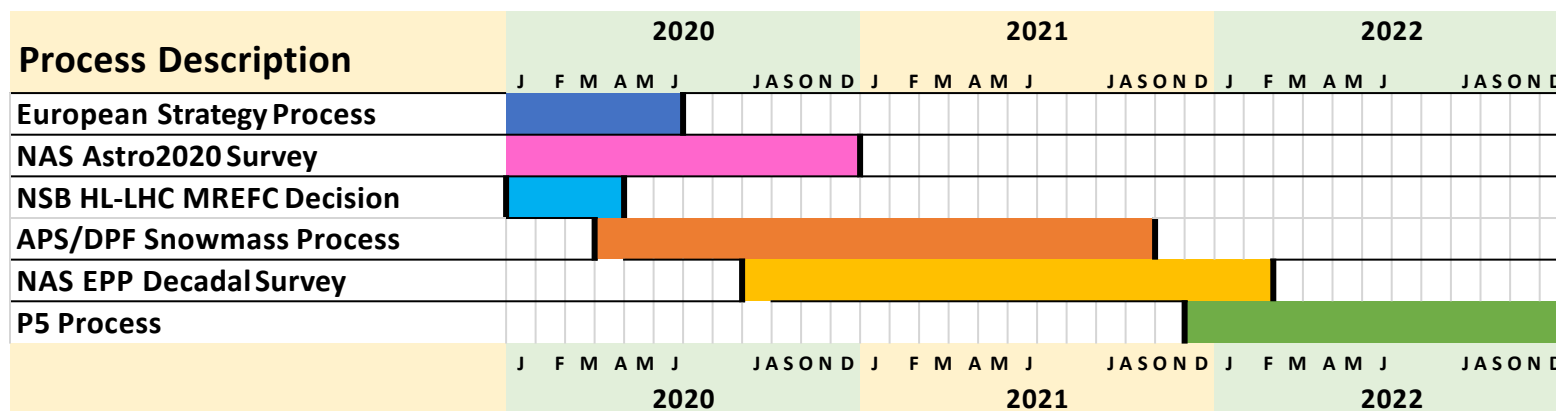
HEP P5 Project Status - Line Item Construction & Major Item of Equipment (MIE)

Subprogram	TPC (\$M)	CD Status	Latest Critical Decision (CD) Date
INTENSITY FRONTIER			
Long Baseline Neutrino Facility / Deep Underground Neutrino Experiment (LBNF/DUNE)	<2600	CD-3A	September 1, 2016
Proton Improvement Project (PIP-II)	653 - 928	CD-1	July 23, 2018
Muon g-2	46.4	CD-4	January 16, 2018
Muon-to-Electron Conversion Experiment (Mu2e)	274	CD-3	July 12, 2016
ENERGY FRONTIER			
LHC ATLAS Detector Phase 1 Upgrade	29.7	CD-4	August 19, 2019
LHC CMS Detector Phase 1 Upgrade	32.2	CD-4	June 10, 2019
High-Luminosity LHC (HL-LHC) Accelerator Upgrade	242.7	CD-3	August 29, 2019
High-Luminosity LHC (HL-LHC) ATLAS Detector Upgrade	149-182	CD-3A	October 16, 2019
High-Luminosity LHC (HL-LHC) CMS Detector Upgrade	144-183	CD-3A	June 8, 2020
COSMIC FRONTIER			
LUX-ZEPLIN (LZ)	55.5	CD-3*	February 9, 2017
Super Cryogenic Dark Matter Search - SNOLAB (SuperCDMS-SNOLAB)	18.6	CD-3	May 2, 2018
Dark Energy Spectroscopic Instrument (DESI)	54.2	CD-4	May 11, 2020
Rubin Observatory LSST Camera (LSSTcam)	168	CD-3	August 27, 2015
Cosmic Microwave Background State 4 (CMB-S4)	TBD	CD-0	July 25, 2019
ADVANCED TECHNOLOGY R&D			
Facility for Advanced Accelerator Experimental Tests II (FACET-II)	25.6	CD-3	June 8, 2018



Community-Wide 2020-2021 U.S. “Snowmass” Process

- HEP community-wide “Snowmass” study process organized by the Division of Particles and Fields (DPF, with DAP+) of the American Physical Society (APS) has begun
- **Status** [Snowmass page: <https://snowmass21.org/start>]
 - Snowmass subgroup meetings nearly weekly
 - Snowmass Planning Meeting, October 5-8 online
 - Final “large” Snowmass Meeting scheduled for July 11-20, 2021 at University of Washington
 - Broad community participation in the HEP strategic planning process is essential
 - PIs and Laboratory Staff are encouraged to be active in all phases of the process
- Next P5 strategy/prioritization process to begin after Snowmass and NAS Decadal Survey, circa end of CY 2021: **P5 report by Nov-Dec 2022 to inform FY 2024 & 2025 U.S. budgets**



Cosmic Frontier Program



Cosmic Frontier Program

Study cosmic acceleration by uncovering the nature of **dark energy**

- ▶ **Imaging surveys map cosmic structure over vast volumes of space:** *Dark Energy Survey (DES)* analysis, *Vera C. Rubin Observatory Camera* nearly ready for commissioning
- ▶ **Spectroscopic surveys build deep, 3D maps of cosmic structure and growth:** *Dark Energy Spectroscopic Instrument (DESI)* ready for observations

Study cosmic acceleration (inflation) at energies near the Planck scale and neutrino properties through the **cosmic microwave background (CMB)** (in partnership with NSF)

- ▶ **South Pole 3rd generation experiment:** *SPT-3G* in operation
- ▶ **Next generation array 10x more sensitive:** *CMB-S4* in planning

Search for **dark matter** through direct detection experiments over a wide mass range

- ▶ **High- and low-mass WIMP sensitivity:** *LZ* ready for CD-4 and *SuperCDMS-SNOLAB*, in fab
- ▶ **Axion (ultralow mass) experiment:** *ADMX-G2* in operation
- ▶ **Small scale future R&D and concept planning**

Explore the unknown – search for New Physics, e.g. relic particles

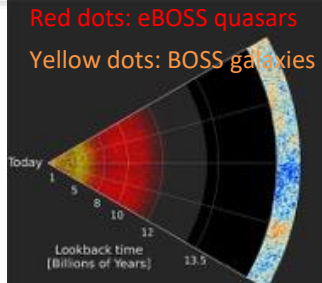
- *AMS* on the *ISS*, *Fermi* mission, *HAWC* in Mexico



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

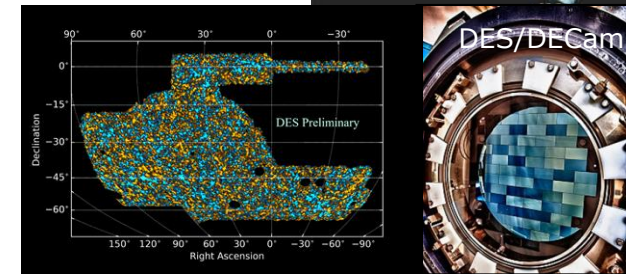


Final Analysis:

- *eBOSS* (spectroscopic) final analysis complete July 2020
- *DES* (imaging) final analysis completes 2021

In Fabrication phase:

- *Vera C. Rubin Observatory* (Rubin LSST, Stage 4 imaging)
 - HEP and NSF-AST (lead agency) partnership; HEP responsible for LSST camera
 - LSST Camera 97% complete; science operations are planned to start in FY2023
 - Planning started for LSST Facility Operations phase and Dark Energy Science Collaboration (DESC) Operations



Survey-ready:

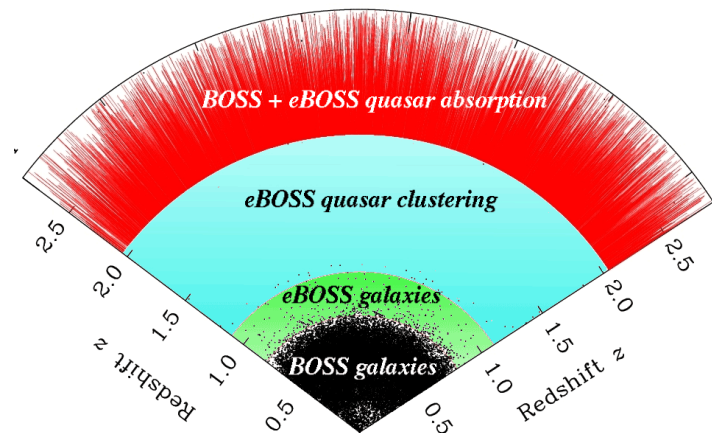
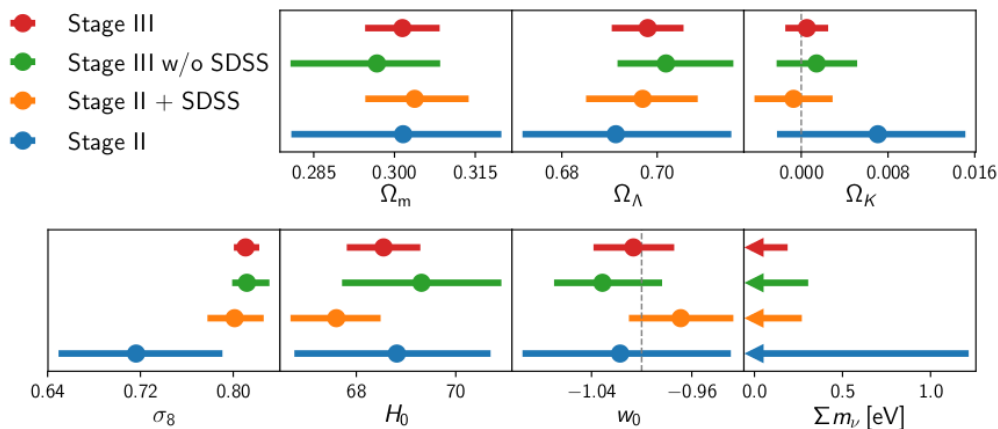
- *Dark Energy Spectroscopic Instrument* (DESI, Stage 4 spectroscopic)
 - DESI commissioning complete March 2020
 - CD-4 May 2020, fabrication complete, ready to operate
 - HEP coordinating w/NSF-AST to “lease” the Mayall telescope; full support for dark energy operations started FY19



Cosmic Frontier Highlight: Extended Baryon Oscillation Spectroscopic Survey (eBOSS)

► Stage 3 Spectroscopic Survey for Dark Energy

- Survey ran 2014-19, precursor to DESI
- Component of the Sloan Digital Sky Survey (SDSS-IV) at Apache Point Obs., NM
- DOE-HEP partnership with Sloan Foundation, US universities and international institutions; 100 collaborators (40 HEP funded) from 34 institutions and 10 countries



► Major Milestone: Final results and papers released July 2020

- BAO/RSD from objects over $0 < z < 2$; BAO from Lyman- α forest and quasars at $z = 2.35$
- Implications for Cosmology:
 - 50X improvement relative to Stage-II in 5-parameter likelihood
 - Stage-III (Planck, SDSS, Pantheon SNe Ia, DES yr1) is 1000X decrease in likelihood volume

Dark Energy Spectroscopic Instrument (DESI)

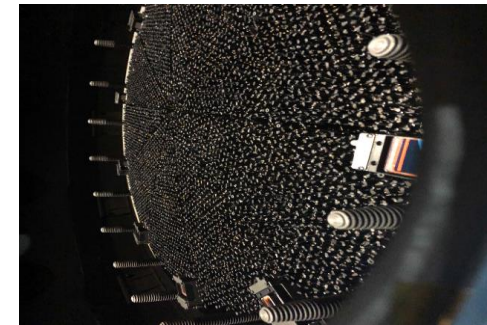
DOE's DESI is ready to take data!

- premier multi-object spectrograph and the first **Stage IV dark energy** project to start operations
- Designed and built through the efforts of a large international collaboration ~ 500 researchers at 75 institutions in 13 nations.
- Partners: STFC, Heising-Simons, Gordon and Betty Moore, France, Mexico, Spain, NSF

→**DOE/LBNL-led** Major Item of Equipment Project to fabricate instrumentation, data management system, upgrades of NSF's Mayall telescope at Kitt Peak; Total Project Cost \$56.328M

- HEP has MOU w/NSF-AST to "lease" the Mayall telescope; full support started in FY2019
- Commissioning complete March 2020, CD-4 May 2020
- Ready to take data and begin 5-year survey mapping the universe in 3D when telescope reopens

→LBNL continues to lead the Operations Phase & Scientific Collaboration



See <https://vimeo.com/422889846>

Vera C. Rubin Observatory



Vera C. Rubin Observatory (renamed Dec. 2019)

- New state of the art observatory on Cerro Pachon in Chile
- For the first ten years of operations, the observatory will perform the wide-field, optical and near-infrared imaging **Legacy Survey of Space and Time (LSST)**, using the **LSST Camera** and the **Simonyi Survey Telescope**.

NSF (AURA) and DOE (SLAC) partnership

- Project: DOE responsible for the Camera; carrying out fabrication & commissioning efforts
- Facility Operations: supported by both agencies; agreed on 50/50 support with planning in full swing.



4 main science themes: probing dark energy and dark matter, inventory of the solar system, exploring the transient optical sky, & mapping the Milky Way.

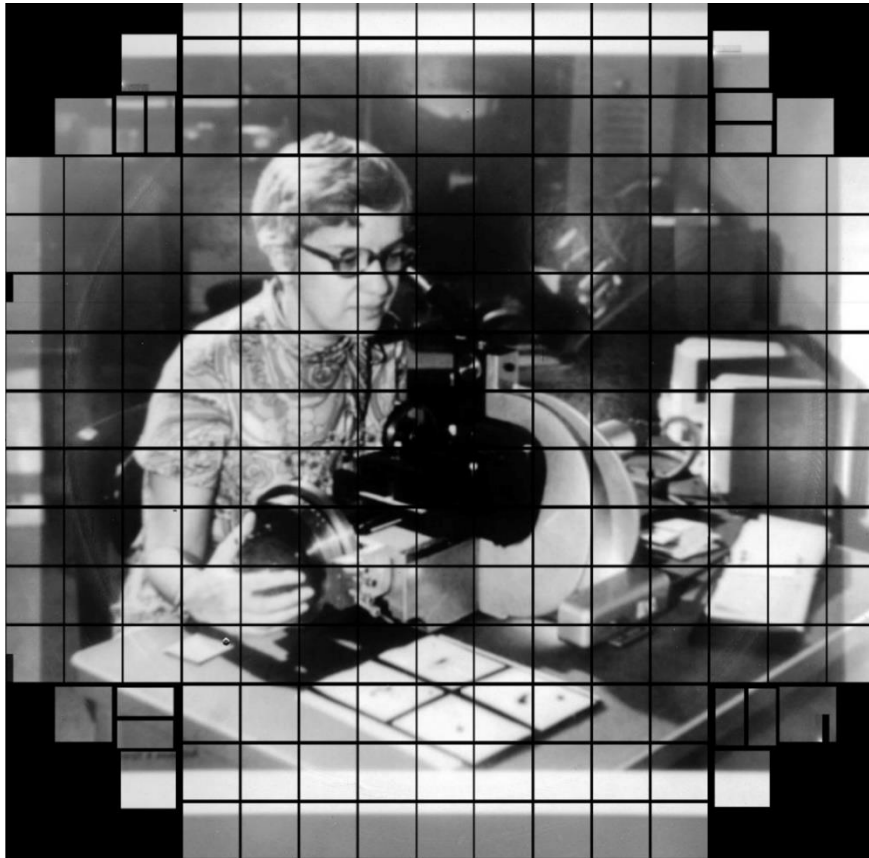
- DOE is participating for the **Stage IV Dark Energy** capabilities; carried out by the Dark Energy Science Collaboration (DESC)

Cosmic Frontier Highlight: Rubin LSST Camera (DOE responsibility)

Full 3.2 Gigapixel image on camera focal plane (thru pinhole projection)

Interactive viewer:

https://www.slac.stanford.edu/~tonyj/osd/public/vera_rubin-2.html

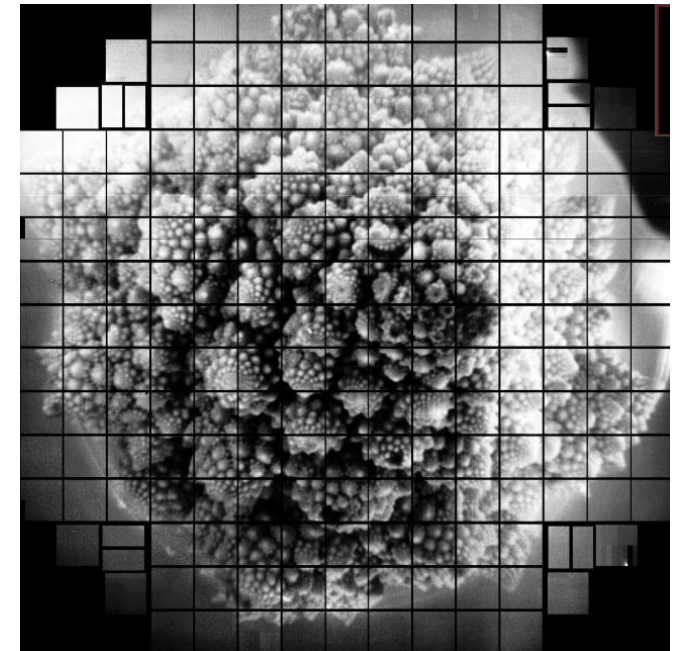


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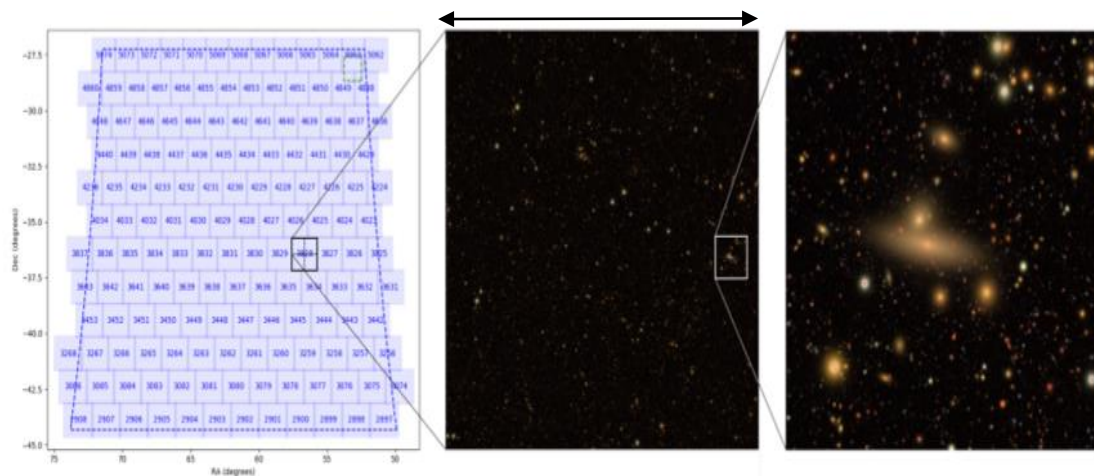
Cosmic Frontier Highlight: LSST Dark Energy Science Collaboration (DESC)

DOE is supporting Dark Energy studies through the LSST DESC

- DESC is developing state-of-the-art software pipelines to carry out cosmological analysis at LSST scale and precision and is testing them using **sophisticated image simulations** and **precursor survey data**.

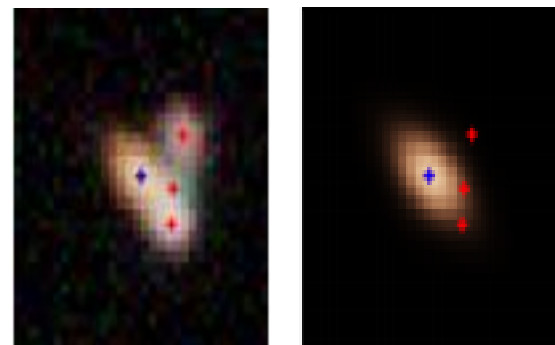


Recent highlights:



Reconstruction (right) of a galaxy within a highly blended system (left) using **novel debrending algorithms**; blending effects are a key systematic uncertainty for LSST DESC.

Image credit: [Arcelin et al. \(2020\)](#).



Area footprint of **high-fidelity LSST image simulations** from DESC's Data Challenge 2 (DC2) on the left; sequentially zoomed images on middle, right. Image credit: Jim Chiang (SLAC), Katrin Heitmann (ANL).

Dark Energy – Next Generation

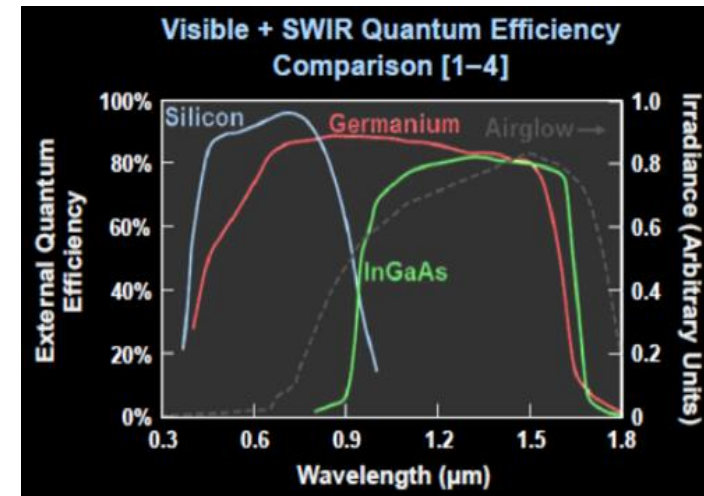
Power of a cosmic survey for precision measurements of cosmological parameters is limited by Redshift accuracy, Redshift range, Statistics

➔ To fully exploit current program of ground- and space-based experiment will require advances in theory, simulations, joint data analysis and computing

- Cross-cutting theory and simulations efforts
- Joint modeling and analysis of imaging, spectroscopic, CMB and other data
- Exascale Cosmological Simulations - Expanding the nonlinear structure frontier, pushing to smaller scales
- Need advances in technologies for Stage 5, methods to increase redshift range, accuracy and statistics.

Community efforts:

- Cosmic Visions Dark Energy group investigating ways to optimize science in DESI/LSST era
 - White paper on small “enhance” efforts in Jan 2018 [arXiv:1802.07216](https://arxiv.org/abs/1802.07216)
- Technology development for Stage 5 surveys, e.g.
 - Germanium CCD R&D
 - “Skipper” CCDs ultra-low readout noise; precision counting of single photons in the optical & NIR
 - Fiber positioner designs to increase density
- HEP community is leading or participating in some concepts
 - White Papers submitted to Astro2020, Snowmass 2021

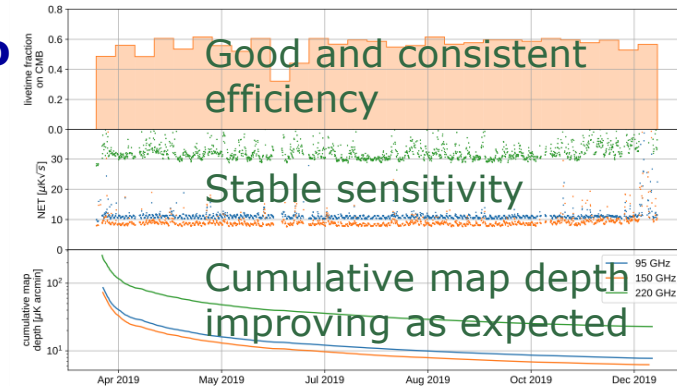


Cosmic Microwave Background

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

Current Experiments:

- HEP (via NERSC computing) participates in science collaborations (e.g. **BICEP**, **PolarBear**) and had a significant role in **Planck**.
- **SPT-3G**: DOE-HEP partnership with NSF
HEP supported major upgrade: fabrication of the 16,000-detector focal plane, greatly increasing instrument sensitivity.



SPT-3G continues operations (since 2017) at full power and high observing efficiency.

P5 Plan:

- **DOE should support CMB experiments as a core particle physics program**
- **CMB-S4 intended to be flagship DOE Cosmic Frontier project in last half 2020s**

→ **CMB-S4 Ground-based Community Collaboration** came together to plan future

- Notional array of several telescopes in Chile & South Pole; ~ 500,000 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> ;

Decadal Survey Reference: <https://arxiv.org/abs/1907.04473>

Cosmic Microwave Background Stage 4 (CMB-S4) Project → Discovery Science!

CMB-S4 recommended by P5 in all scenarios

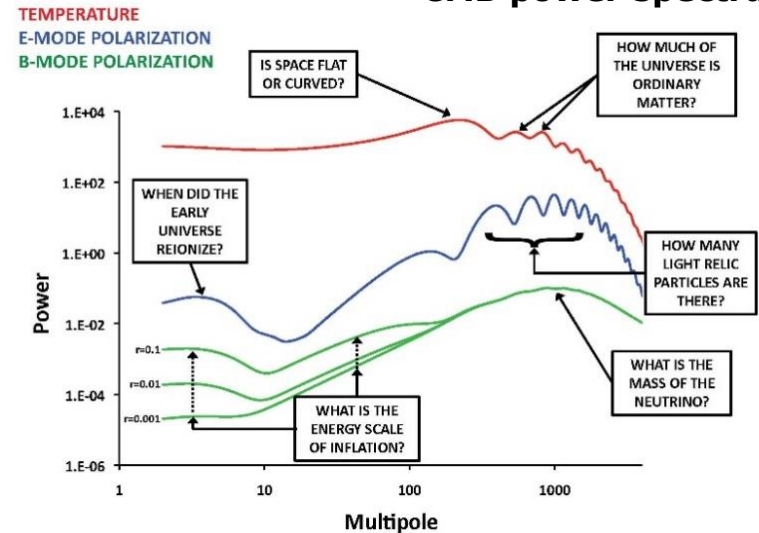
Goal: cross critical science thresholds

Highlights:

2 sites: Chile, South Pole

- Ultra-deep “r” survey $\geq 3\%$ of sky + delensing
- Deep & wide N_{eff} & Legacy Survey $\sim 60\%$ of sky
- Large & small telescopes
- 500,000 cryogenic sensors, superconducting readout

Ultra-precision measurement of CMB power spectrum



Science	Stage 2	Stage 3	Stage 4	Top Level goal for CMB-S4
Inflation “r”	≤ 0.1	≤ 0.01	≤ 0.001	Detect/rule out classes of inflationary models
$\sigma(N_{\text{eff}})$	0.14	0.06	0.03	Detect/rule out light relic particles w/ spin
$\sigma(M_{\nu})$	0.15eV	0.06eV	0.02eV	3σ detection
# detectors	~ 1000	$\sim 10,000$	$\sim 500,000$	Deployed on multiple telescopes
Sensitivity (μK^{-2})	10^5	10^8	10^8	2° to $1'$ angular scales

CMB-S4 planning, status

Envisioned as a \$600M TPC multiagency project: Plan HEP (lead) & 3 NSF divisions
Interim Project Office (IPO) – set up after 2017 AAAC Concept Definition Taskforce

- Developed a technically driven schedule
- Carrying out technical studies, concept design, planning
- Assessments: Detector fab 2019, Optical coupling May 2020, Readout June 2020

NAS Astro2020 Decadal Survey underway

- July 2019 White Paper; Fall 2019 RFI, Feb. 2020 Q&A, TRACE March 2020

DOE Status:

- **Approved Critical Decision 0 (CD-0) “Mission Need” in July 2019**
 - HEP support for Project planning (FY20 \$2.4M) technology and Lab R&D
 - Working to support the IPO timeline of FY2021 CD-1/3a
- **Selected LBNL to lead our efforts Aug. 2020**
- **Status review, Aug 18-20, successful**
- **FY21 President’s Request – new MIE Project start**
- **HEP is excited about moving forward!**

DOE & NSF: Weekly Joint Oversight Group (JOG) meetings

NSF MSRI-R1 to U. Chicago (Sept 2019) to begin work on Preliminary Design



Direct Detection of Dark Matter

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

3 Dark Matter 2nd Generation (DM-G2) projects

Operating: ADMX-G2 axion search (μeV - meV mass) at UWash (HEP)

Projects in Fab/Commissioning:

LZ at Homestake Mine in South Dakota (HEP)

- WIMP search through dual phase liquid Xe; ~ 10 - 1000 GeV mass
- Deliverables complete; CD-4 review Aug 2020

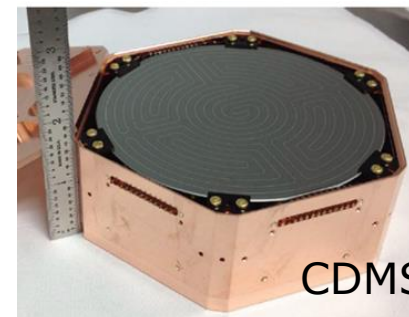
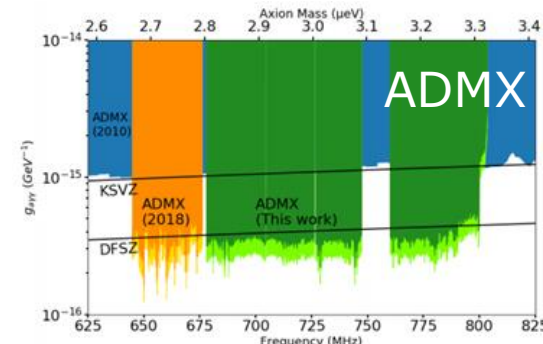
SuperCDMS-SNOLab in Canada (HEP+NSF-PHY partnership)

- WIMP search using cryogenic solid-state crystals; ~ 1 - 10 GeV mass
- Project in fabrication; Delays due to cryostat procurement & Covid-19; CD-4 \sim FY22

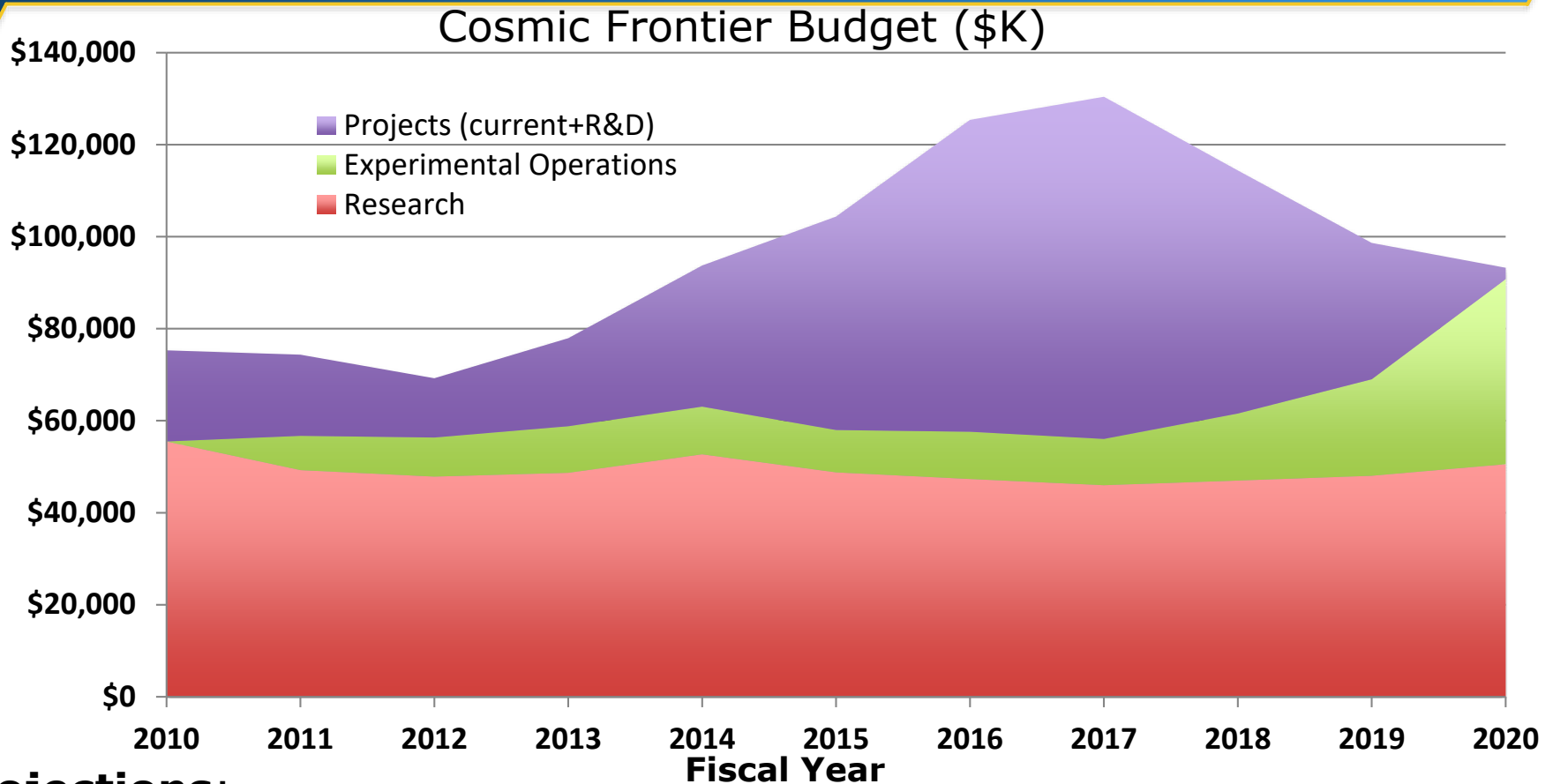
Future Planning: Dark Matter New Initiative for small projects in new areas of phase space:

6 funded efforts for concept studies & technology R&D

→ 4 Cosmic Frontier & 2 Intensity Frontier (accelerator-based)



Cosmic Frontier Budget History (FY10-20)



Projections:

- **Experimental Operations:** As the current Projects complete, estimated needs ramps up to ~ \$55M to \$60M by FY2024; levels to ~ \$40M by FY2030.
- **Future opportunities:** Compelling Cosmic Frontier Projects will be considered and supported within available overall HEP Project funds. Guidance from Astro2020, next P5.

HEP Cosmic Frontier Budget: FY 18-21

HEP (\$K)	FY18	FY19	FY20	FY20	FY21
Cosmic Frontier	Actual	Actual	enacted	Actual	request
Research	47,008	48,053	48,072	50,545	29,220
Facility Ops	14,570	20,957	41,358	40,235	37,400
Projects	52,835	29,615	2,000	2,450	1,000
SBIR	2,487	2,869	3,471	3,524	2,300
TOTAL	116,900	101,494	94,901	96,754	69,920

FY20 appropriation:

Cosmic Project changes: -26.35M DESI, LZ, SuperCDMS-SNOLAB projects; +2M CMB-S4
Cosmic Operations ramps up > \$20M for Rubin Observatory, LZ, DESI, SuperCDMS-SNOLAB

HEP Cosmic Frontier	FY18	FY19	FY20	FY21
MIE Projects (\$K)	Actual	Actual	Actual	request
LSST Camera	9,800			
DESI	20,000	9,350		
LZ	14,100	14,450		
SuperCDMS SNOLAB	7,400	2,550		
CMB-S4			2,450	1,000

HEP Efforts related to the Cosmic Frontier

Theory program

- Vibrant Theory Program supporting all areas including Cosmic Frontier

Advanced Detector Development & Accelerator R&D programs:

- ▶ Active R&D developing next generation detectors, including CCDs, TES superconducting bolometers, MKIDs, readout electronics, optics, fiber positioners.

High Performance Computing, Computational HEP program

- **DOE Supercomputer allocation** coordination via various ASCR and DOE Competitions
 - ▶ Computational HEP, SCIDAC – focused computational challenges
 - ▶ NERSC facility allocations for Cosmic Frontier Simulations, Data Processing, Analysis
- **High Performance Computing** → Exascale; Comp HEP & ASCR coordination & partnerships on some efforts, including Cosmic Simulation and Data analytics
- **HEP Center for Computational Excellence (CCE)** investigates ways to optimize code
- **HEP Computing Infrastructure Working Group** formed in 2017 to develop a strategy for meeting the computing needs, since projected needs are larger than availability
- **SciDAC** is an Office of Science program where ASCR and HEP jointly fund efforts, e.g. SciDAC 4.

HEP Initiatives (\$K)	FY19	FY20	FY21 PRB
AI/ML	3,750	15,000	34,500
QIS	27,500	28,500	43,809
Microelectronics			5,000

New Initiatives – quickly growing areas

- **Quantum Information Science (QIS)**
 - ▶ Powerful new windows to accomplish HEP mission & advance QIS Foundational theory, computing, sensors (enable dark matter searches, CMB), technology, experiments; DOD, NIST
- **Artificial Intelligence, Machine Learning – rapidly growing area in SC**
 - ▶ Key element of experiment design, operation, and analysis
 - ▶ FY 2020 appropriations provided dedicated funds in SC & HEP to advance AI/ML initiatives
- **Microelectronics Initiative (in FY2021 request)**
 - ▶ SC offices (ASCR, BES, FES, HEP) partnering to support multi-disciplinary microelectronics research



2020 HEP PI Meeting

- ▶ The 2020 HEP University PI Meeting took place online August 24-26. All talks at <https://www.orau.gov/heppi2020>
- ▶ HEP overall program talks & Program Manager talks on each subprogram (e.g. Cosmic Frontier)
 - ▶ Opportunities for one-on-one meetings with Program Managers

HEP PI meetings traditionally take place every summer, in conjunction with APS/DPF every other year



Meeting of the Division of Particles & Fields of the American Physical Society

DPF2019

July 29-August 2
Northeastern University
Boston, MA
dpf2019.northeastern.edu



Virtual HEP PI Meeting

Sponsored by the U.S. Department of Energy
Office of Science
August 24-26, 2020



Northeastern College of Science

Program Committee:

Toyoko Orito (U. of California)	André de Groot (Northeastern U.)	Young-Kee Kim (U. of Chicago)	Steven Ritz (U. of California Santa Cruz)	Stefan Scherer (U. of Manchester)
George Alverson (Northeastern U.)	Enrico Dattoli (INFN)	Raffael Lang (U. of Illinois)	Kate Scholberg (U. of Michigan)	Tim Tait (U. of Cambridge)
Priscilla Cushman (U. of Minnesota)	Hassan Jawahery (U. of Maryland)	Michael Peskin (SLAC)	Luise Stenlund (Northeastern U.)	Stephanie Wilberg (U. of Massachusetts Amherst)
			Marcelle Soares-Santos (Brandeis U.)	Darlen Wood (Northeastern U.)



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COVID-19 Impacts - Research

- ▶ 2 HEPAP surveys – community (300+ respondents), PIs (100+)

Presented at HEPAP <https://science.osti.gov/hep/hepap/Meetings/202007>

- ▶ HEP survey of experimental collaborations (>90% response)

Plenary session at HEP PI meeting Aug 2020

https://www.ornl.gov/heppi2020/presentations/day02/Plenary_130-215_Impacts_of_COVID_Crawford.pdf

Current HEP policy: Maximum flexibility for changes in current/new research awards, e.g.:

- ▶ Extending student and postdoc terms, converting travel funds
- ▶ “switching” thesis experiments due to delays in data

Further possibilities open up if new, “stimulus” funding.



Diversity, Equity, Inclusion

Please see tomorrow's panel with Dr. Julie Carruthers, DOE Office of Science. Also, full presentation to HEPAP

<https://science.osti.gov/hep/hepap/Meetings/202007>

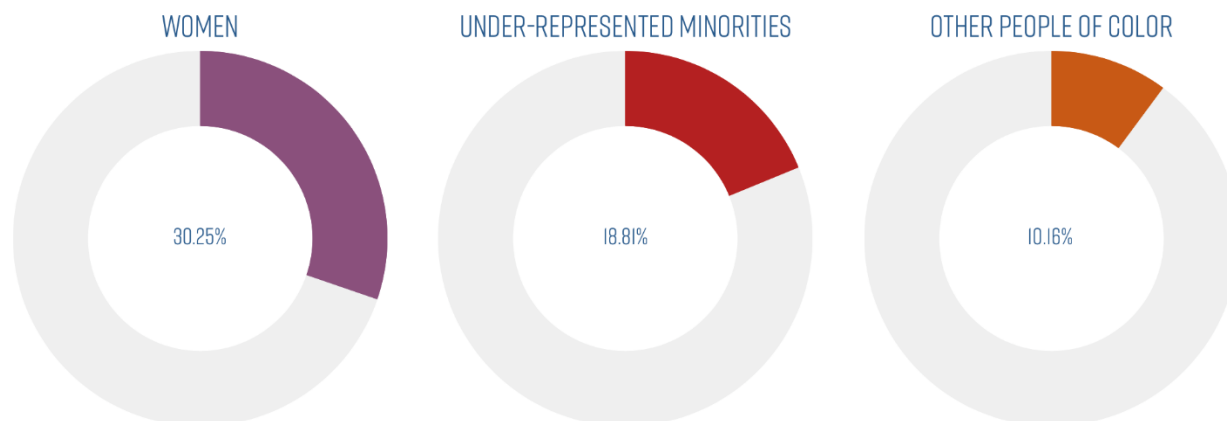
Interactive data at <http://nationallabs.org/staff/diversity/>

DEMOGRAPHIC DATA FOR THE NATIONAL LABS

CHANGE DATA VIEW:



ALL JOBS



Responses to AAAC Report Recommendations

The following set of slides address the AAAC 2019-2020 annual report recommendations directly impacting DOE.



AAAC: InterAgency Coordination and Cooperation

Topic: Interagency coordination and collaboration to maximize return on investments in survey datasets

Finding: NSF, NASA and DOE are continuing to work together to accomplish large research projects that were prioritized in the National Academies 2010 Decadal Survey of Astronomy & Astrophysics (NWNH) report and in the 2014 P5 report to DOE and NSF/PHY.

Recommendation: NASA, NSF, and DOE/Cosmic Frontier should work together to enable data discoverability across their data archives via joint adoption of standards in order to maximize science return.

Recommendation: All current and planned surveys supported by NSF, NASA and DOE/Cosmic Frontier should publicly release their data with suitable access tools and documentation. This is consistent with the AAAC Principles of Access recommended by the AAAC in their 2013-2014 annual report. In addition, the surveys should endeavor to use open code to create the data products in order that the community can learn how those data products were created.

Recommendation: NASA, NSF, & DOE/Cosmic Frontier should include funding to enable adequate public access to the data, software, & data products of the surveys.

Response: DOE follows AAAC Principles of Access for data accessibility and DOE SC guidance <https://science.osti.gov/Funding-Opportunities/Digital-Data-Management> and will provide data support in balance with other research and computational funding commitments.

AAAC: InterAgency Coordination and Cooperation

Recommendation: The three agencies should coordinate on the guidelines and expectations for the public releases of data sets, data products, data access tools, and related software used to produce future survey results, astrophysical simulations, and missions. The goal of this coordination should be to help researchers efficiently provide access to the data they produce through tools useful for the broad scientific community with minimal duplication of effort between agencies and stakeholder groups. Release and documentation of the software used to generate and analyze the data will enhance the quality of current and future science by enabling more cost-effective reproducibility and extension of the scientific results from the initial studies.

Response: DOE/Cosmic Frontier coordinates with partnering agencies on an experiment through Joint Oversight Groups and similar groups. Operations plans include specification of public data releases.

Recommendation: The agencies and the AAAC should initiate a review of the Principles of Access after the release of the 2020 Decadal Survey recommendations.

Response: We look forward to both the Decadal Survey and next AAAC report. Note that OSTP was involved in the 2013-2014 Principles of Access report.

AAAC: Protecting Electromagnetic Spectrum

Topic: Protecting the Electromagnetic Spectrum for Astronomical Research

Finding: The emergence of mega-constellations of low earth orbit satellites represents a serious issue for astronomical observations. The reflectivity of these satellites and their radio transmissions impact the scientific returns of current and future investments in astronomical facilities across the optical and radio spectrum.

Recommendation: The AAAC recommends that NASA, NSF, and DOE/Cosmic Frontier develop a coordinated strategy to address the short-term impacts of the Starlink program on their facilities and missions, as well as the longer-term definition of policies to address the impact of future mega-constellations.

Response: Multiple agencies (beyond the science agencies) are involved and studies are underway, e.g. JASON, National Academies, and the AAS. The JASON study was charged by NSF, with coordination and participation by DOE, and the letter report was released last week, the full report to follow. DOE/Cosmic Frontier expects to follow the lead of NSF and NASA.



AAAC: Diversity and Inclusion

Topic: Ensuring a Diverse and Inclusive Community:

Finding: The agencies are making and planning important and impactful changes to improve diversity and inclusion & to reduce implicit bias across their portfolios.

Recommendation: NASA/APD, NSF/AST, and DOE/Cosmic Frontier should learn from each other's initiatives and evaluate adopting joint priorities and policies across their Diversity and Inclusion efforts.

Recommendation: NASA, NSF, and DOE/Cosmic Frontier should report annually to the AAAC on their diversity and inclusion initiatives, and where possible provide quantitative evaluations of the impacts of these initiatives. The agencies should furthermore report on efforts to remove implicit bias in proposal reviews.

Response: DOE SC is presenting to AAAC at this meeting on DEI efforts. Instructions concerning implicit bias are part of every proposal review. HEP follows the DOE SC DEI plan and recommendations.

Recommendation: The AAAC recommends that the agencies adopt or maintain policies regarding postdoctoral fellows to support the community of early-career scientists in astronomy and astrophysics.

Response: DOE/HEP postdocs are already employed directly by institutions as part of PI grants, with all benefits of employees. DOE/HEP strives to ensure postdocs have stable support within the context of PI grants. The DOE/SC Early Career Research Program had its largest selection of awardees in HEP ever in FY20.

AAAC: Implementation of Astro2010 Recommendations

Topic: Implementation of Astro2010 Decadal Survey Recommendations:

Finding: The AAAC is gratified to see continued, significant progress by the NSF and DOE toward completion of the highest priority decadal ground-based facility, the Vera C. Rubin Observatory, which is advancing toward the start of survey science operations in 2022.

Finding: Operations of the Rubin Observatory may place significant strain on the ability for NSF and DOE/Cosmic Frontier to maintain a balanced portfolio of facilities and other funding.

Recommendation: The AAAC urges NSF and DOE to put in place a long-term operations plan that will, while maintaining a balanced overall portfolio, ensure that the US science community can capitalize on the substantial investment in the Rubin Observatory.

Response: DOE/HEP is actively involved in such planning, with the most recent review of Rubin Observatory operations in April 2020. DOE/HEP agreed in May 2019 to jointly support ($\sim 50/50$) Rubin operations with NSF.



AAAC: FY2021 Budget Concerns

Topic: Increase budgets

Recommendation: The AAAC urges Congress to increase the proposed FY 2021 appropriation for DOE High Energy Physics above the Administration's request to provide adequate funding for operations of and research and analysis of data from the numerous world-class facilities currently nearing completion.

Response: DOE/HEP appreciates the support and recognizes the importance of funding for operations and research areas. The House mark for FY21 is above the Administration request but no final appropriation information is available.



Research Support



Early Career Awards – Cosmic Frontier

FY20:



Hugh Lippincott
Dark Matter



Lado Samushia
Dark Energy



Michael Troxel
Dark Energy

FY19:



Tim Eifler
Dark Energy



Scott Hertel
Dark Matter



Elisabeth Krause
Dark Energy

FY18:



Alexie Leauthaud
Dark Energy



Hee-Jong Seo
Dark Energy

2021 Breakthrough Prizes – New Horizons

2021 New Horizons in Physics Prizes – DOE-HEP funded winners



Tracy Slatyer
Particle Astrophysics
DOE Early Career Award FY15



Rouven Essig
Sub-GeV Dark Matter



Javier Tiffenberg
Sub-GeV Dark Matter
DOE Early Career Award FY18



Netta Engelhardt
Quantum Information of
Black Holes

Summary

- ▶ Excellent science results continue to be produced from our operating experiments!
- ▶ P5 strategic plan is supported by Community and broad support is enabling it to be fully implemented.
- ▶ FY2021 House (and eventually Senate) Marks are “budget indicators”
- ▶ HEP and community are working to balance research and operations needs with project funds to carry out an optimal program



Cosmic Frontier News:

- **DESI** ready to operate
- **LZ** completing fabrication (CD-4 expected Sept.2020)
- **CMB-S4** has DOE CD-0; LBNL selected as Lead Lab for DOE scope; Continue progress towards CD-1
- **Rubin LSSTcam** nearly complete; Commissioning ongoing; Operations in planning
- Dark Matter small project planning underway.

Significant future planning – looking forward to Astro2020 and Snowmass/P5 for exciting opportunities & directions!





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