



U.S. DEPARTMENT OF
ENERGY

Office of
Science

Office of High Energy Physics (HEP) Program and Budget Report

Astronomy & Astrophysics Advisory Committee (AAAC)

September 26, 2019

Kathy Turner, Cosmic Frontier Program Manager

+ Karen Byrum (Detailee), Drew Baden (IPA), Eric Linder (IPA)

OUTLINE

- Mission, Organization
- Guidance, Planning, Execution
- Budget
- Cosmic Frontier Details
 - Dark Energy
 - CMB
 - Dark Matter
 - Cosmic, Gamma
 - Other news
- AAAC recommendations, response
- Grants, Funding
- Summary



Mission of the Department of Energy

The mission of the Energy Department is to ensure America's security and prosperity by addressing its energy, environmental and nuclear challenges through transformative science and technology solutions.

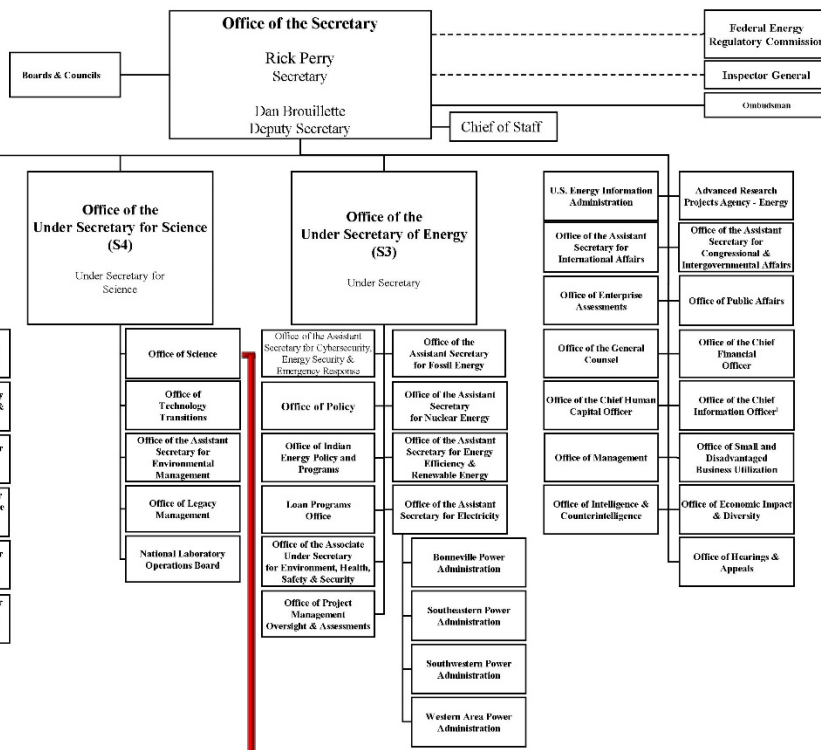
- ▶ Catalyze the timely, material, and efficient transformation of the nation's energy system and secure U.S. leadership in clean energy technologies.
- ▶ **Maintain a vibrant U.S. effort in science and engineering as a cornerstone of our economic prosperity with clear leadership in strategic areas.**
- ▶ Enhance nuclear security through defense, nonproliferation, and environmental efforts.
- ▶ Establish an operational and adaptable framework that combines the best wisdom of all Department stakeholders to maximize mission success.



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





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Office of High Energy Physics
James Siegrist, Director
Carol Atherton (Contractor)

HEP Budget and Planning: Erin Cruz, Michelle Bandy, Alan Stone, Michael Cooke

International Agreements Program: Alastair Cairns, Alastair Cairns

Research & Technology Division
Glen Crawford, Director

Facilities Division
Mike Procaro, Director

Research & Technology Division:

- Janice Hauman
- Elaine Perkins (Contractor)
- Andrew Peterson (AAAS Fellow)
- Claudette Rosado-Reyes (AAAS Fellow)
- Chastie Ashton
- David Bogley

Facilities Division:

- Accelerator Stewardship: Eric Colby
- HEP Operations: Kathy Yarnas
- HEP Connections: Lal Chatterjee

Research & Technology Division:

- Physics Research:**
 - Energy Frontier: Alastair Cairns, Thomas McLeone (Detailee)
 - Intensity Frontier: Glen Crawford (Acting), Michael Cooke, Kevin Flood (IPA), Laurence Littenberg (Detailee)
 - Cosmic Frontier: Kathy Turner, Drew Baden (IPA), Eric Lindner (IPA), Karan Bhatia (Detailee)
- Research Technology:**
 - General Accelerator R&D: L.K. Lin, John Siegel, Eric Colby, Ken Marken
 - Detector R&D: Holmström Marlskie
 - Computational HEP & GIS: Lal Chatterjee
 - SBIR/STTR: Ken Marken

Facilities Division:

- Facility Operations:**
 - Fermilab Complex: John Kogut
 - LHC Operations: Alastair Cairns
 - Other Operations (SLAC/Other Labs): John Kogut
- Facility Development:**
 - LARP: Bruce Strauss
- Instrumentation & Major Systems:**
 - ATLAS Upgrade—Simona Rolli
 - CMS Upgrade—Simona Rolli
 - DESI—Kathy Turner
 - FACET—Ted Lavin
 - HL-LHC ATLAS—Simona Rolli
 - HL-LHC AMP—Simona Rolli
 - HL-LHC CMS—Simona Rolli
 - BNF-DUNE—Bill Wineski (Detailee)
 - LSS/TC—Holmström Marlskie
 - LZ—Ted Lavin
 - MzD—Ted Lavin
 - PPF—Mike Harrison (Detailee)
 - SuperCDMS-SNO+—Simona Rolli



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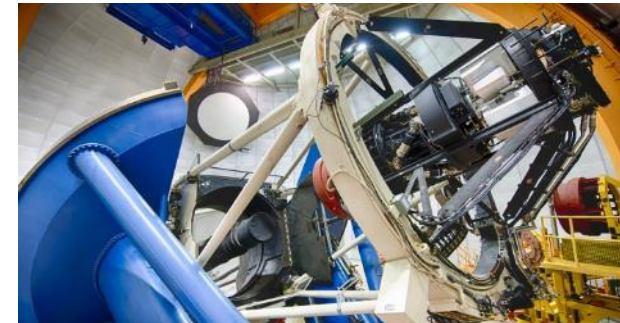
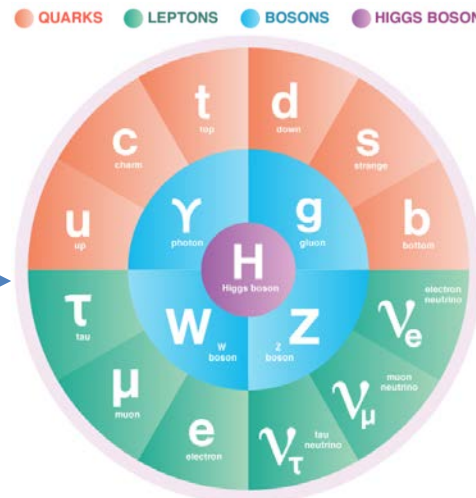
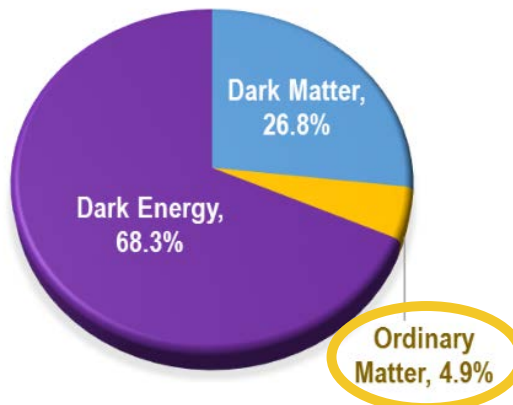
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Office of High Energy Physics (HEP) Program Mission

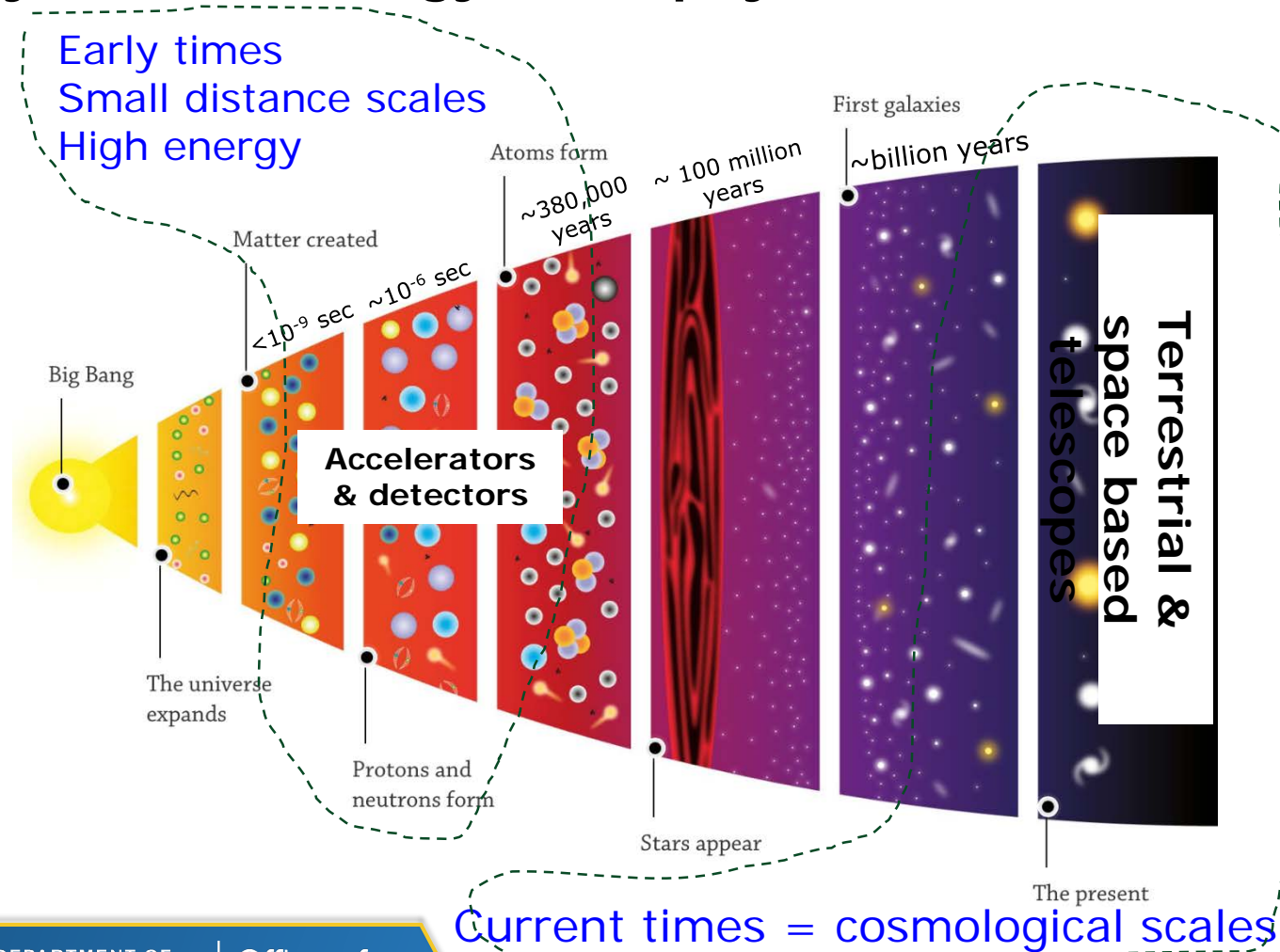
... is to understand how the universe works at its most fundamental level:

- ▶ 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



From Quarks to the Cosmos

→ Scientific Areas are intertwined: High Energy/Particle Physics, Cosmology, Astrophysics, and Astronomy.

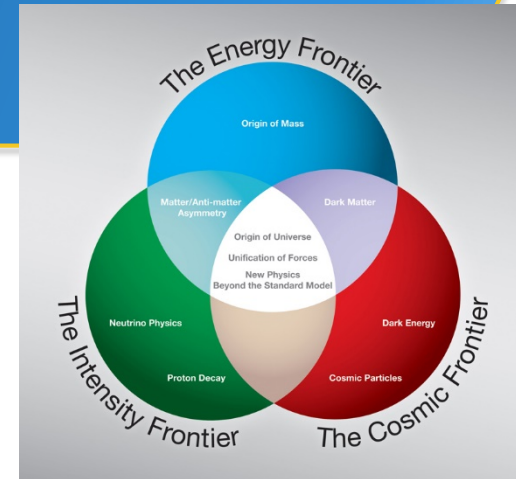


HEP Program Layout

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)

Areas of study to fully carry out the program:

- ▶ Theoretical research
- ▶ High Performance Computing → Exascale; Artificial Intelligence/Machine-learning
- ▶ State-of-the-Art Detector and Accelerator technology development
- ▶ Quantum Information Science (QIS) is a quickly-growing area.





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Program Guidance, Planning, Execution

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 HEP program**
- ▶ Subpanels for detailed studies (e.g. **Particle Physics Project Prioritization Panel, “P5”**, in 2008, 2014 – Our Strategic Plan)
- ▶ **Astronomy and Astrophysics Advisory Committee (AAAC)**
 - ▶ Advises DOE, NASA, and NSF on selected issues in astronomy & astrophysics of overlap, mutual interest and concern

Formal 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:

- ▶ Community science studies and input (e.g. Snowmass, Dark Energy Task Force, DPF input).
- ▶ CMB-S4 Concept Design Team (CDT), Gemini-Blanco-SOAR Telescopes roles subpanels of AAAC
- ▶ Significant Interagency and International Partnerships & Coordination – this is a global field!
- ▶ Astro-Particle International Forum (APIF) – Agency-level international group
- ▶ Tri-Agency Group (TAG) – DOE, NASA, NSF-AST meetings on LSST, 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 & DESI
- **Dark Matter:** direct detection search suite of “generation 2” 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



HEP & The Astro2020 Decadal Survey

NASA, NSF and DOE worked together to deliver a statement of task (SOT) to the National Academy of Sciences for Astro2020

- Identify the most compelling science challenges and frontiers in astronomy and astrophysics, which shall motivate the committee's strategy for the future;
- Develop a comprehensive research strategy to advance the frontiers of astronomy and astrophysics for the period 2022-2032.
 - In addition to projects & experiments, consider need for Research/Scientist support, Experimental Operations, Computing resources, technology development, etc.

→Guidance from Astro2020 will inform HEP on

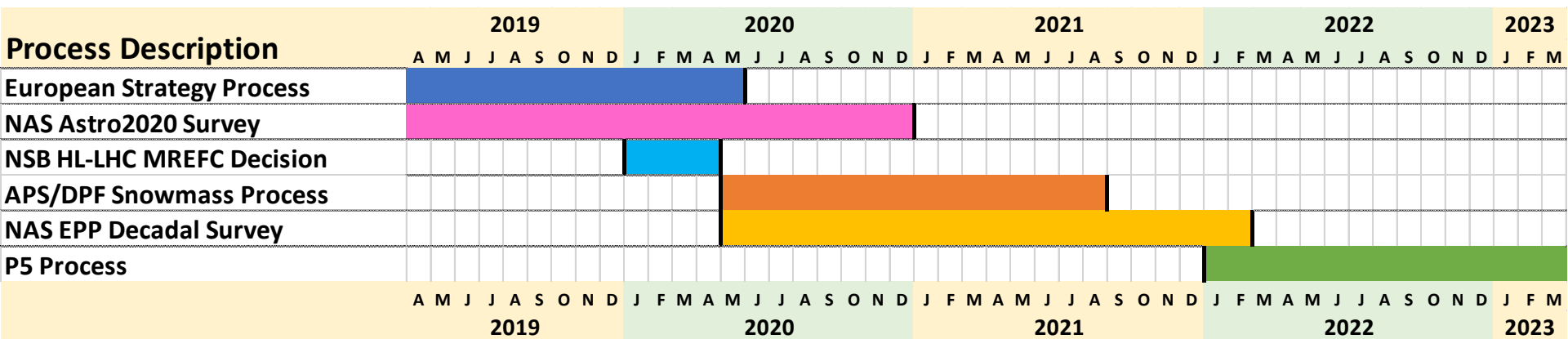
- Compelling, high impact science directions and research strategies
- Opportunities for HEP to make contributions to:
 - select, high impact experiments with discovery potential
 - that address HEP science goals
 - where DOE HEP researchers and investments can play a significant role in & make unique, significant & necessary contributions (PASAG criteria)
- Partnerships with NASA, NSF & international collaborators as appropriate



Possible Strategic Planning Timeline

From a DOE perspective, the earliest that new APS/DPF Snowmass, NAS Elementary Particle Physics Decadal Survey, and P5 strategic plan processes could begin is 2020

- ▶ Relative timing of Snowmass, P5, and NAS EPP Decadal Survey to be determined; Snowmass starting summer 2020
- ▶ Enables receiving next P5 recommendations by March 2023, in time to inform FY 2025 budget formulation



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 research efforts directly in line with HEP program & project priorities, responsibilities & science goals

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

- Therefore, consider 2009 PASAG report criteria to determine where, and at what level HEP participates in specific projects that make significant advances in science
 - Particularly where HEP community brings unique or leadership contributions

Particle Physics is Global

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



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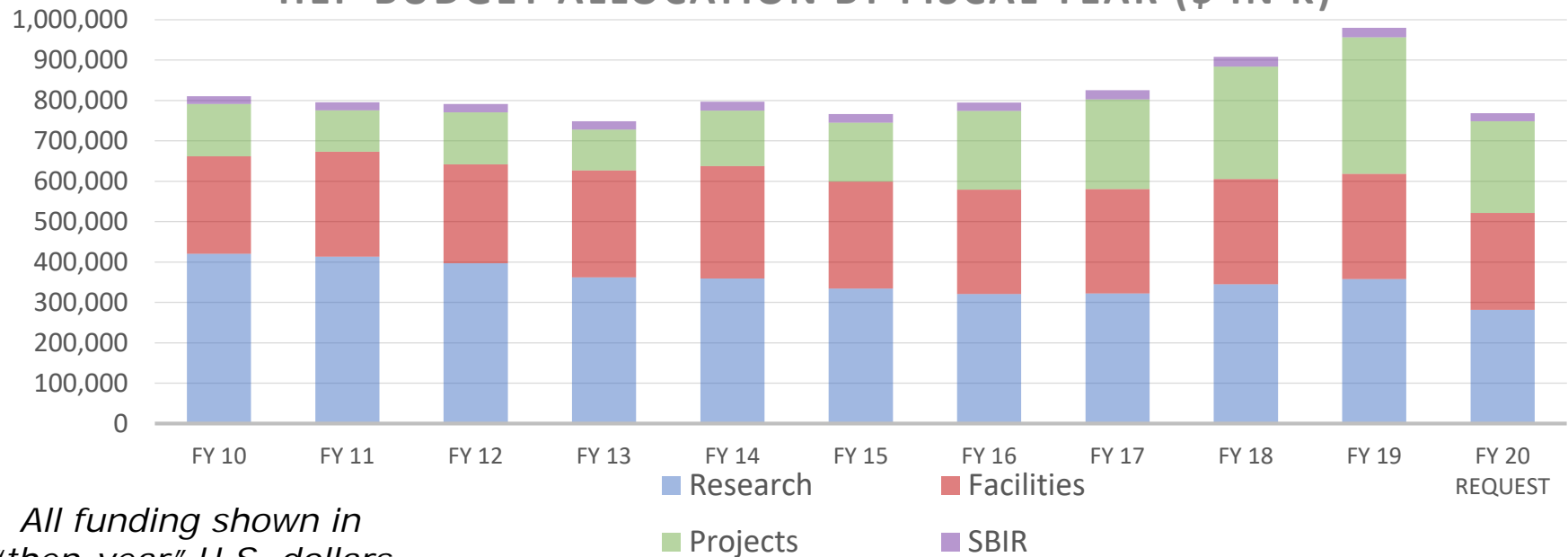
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Budget

Budget: Overall HEP Trend

- ▶ P5 strategy continues to define investments for the future

HEP BUDGET ALLOCATION BY FISCAL YEAR (\$ IN K)

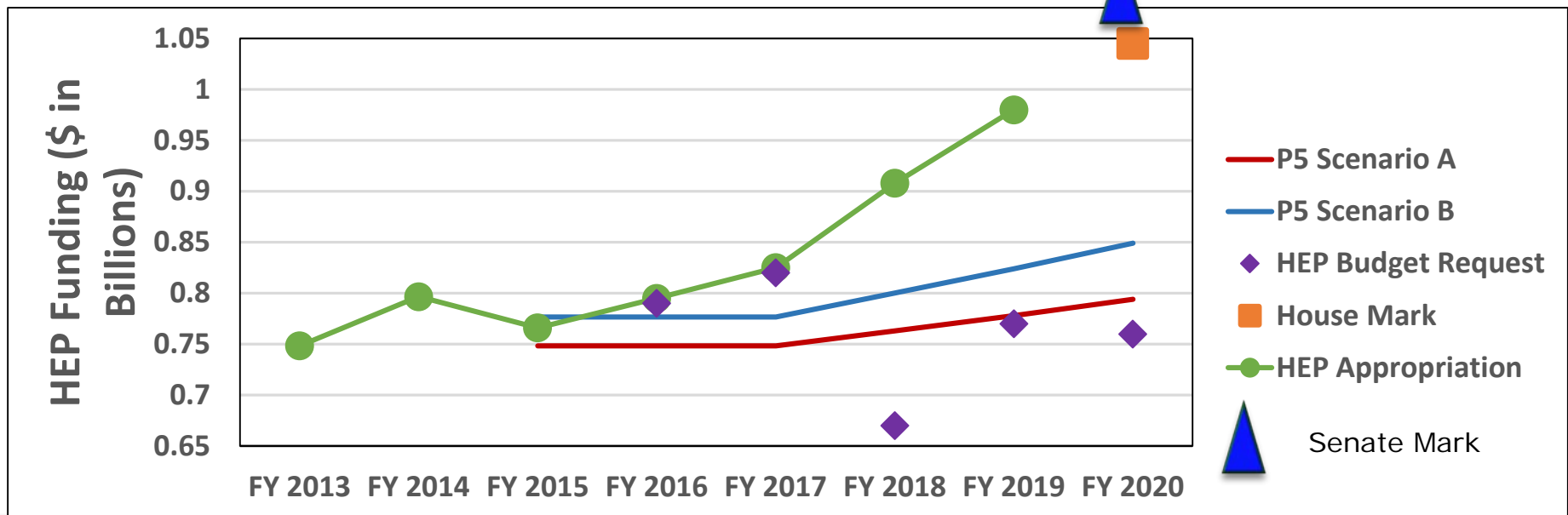


- **Research**: primarily supports scientists participating in all aspects of an experiment (design, fabrication, operations, data planning & analysis)
- **Experimental/Facility Operations** and **Projects**: primarily supports technical personnel, materials, supplies, procurements, consumables



U.S. Congress Supports P5 Strategy

- ▶ Congressional appropriations reflect strong support for P5
- ▶ Recent appropriations reports include language recognizing community's efforts:
 - ▶ FY19 Senate EWD: "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..."



HEP Budget: FY 2019 Enacted & 2020 Request

HEP Funding Category (\$ in K)	FY 2018 Actual	FY 2019 Enacted	FY 2020 Request	FY 2020 vs. FY 2019
Research	359,177	380,847	301,357	-79,490
Facilities/Operations	270,488	260,803	239,746	-21,057
Projects	278,335	338,350	226,935	-111,415
Total	908,000	980,000	768,038	-211,962

- ▶ **FY 2019 Enacted Budget continues support for P5-guided investments in mid- & 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
 - Operations support enables world-class research at HEP User Facilities
- ▶ **FY 2020 Request supports balanced program of world-leading research, facilities and projects**
 - Quantum Information Science: SC-wide initiative to accelerate discovery
 - Artificial Intelligence (AI)-Machine Learning (ML) research to tackle challenges across HEP
 - Cosmic Microwave Background Stage 4 (CMB-S4) R&D to develop large-scale project



FY 2020 House & Senate Marks

DOE Office of Science **House Mark \$6.87B** (**Senate Mark \$7.22B**)

- ▶ \$285M above FY19 enacted and \$1.32B above FY20 request
- ▶ Supports Artificial Intelligence (AI)

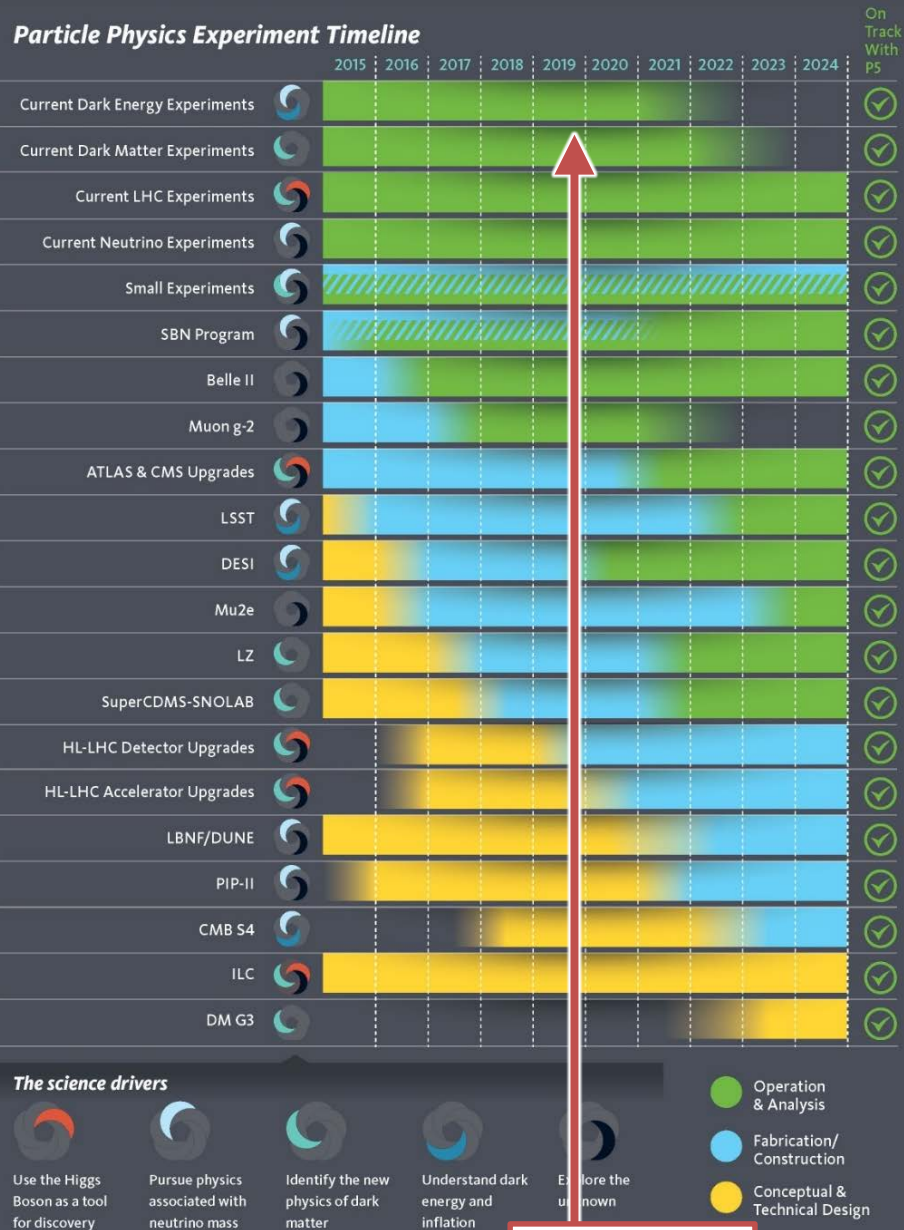
High Energy Physics **House Mark: \$1.045B** (**Senate Mark \$1.065B**)

- ▶ [HEP Core Program]—Within available funds, the recommendation provides \$25,000,000 for the Sanford Underground Research Facility, not less than \$50,000,000 for Accelerator R&D, and \$97,975,000 for the HL-LHC Upgrade Projects.
- ▶ The Committee strongly urges the Department to **maintain a balanced portfolio** of small, medium, and large scale experiments, and to **ensure adequate funding for research** performed at universities and the national laboratories. The Committee encourages DOE to fund facility operations at levels for **optimal operations**.

HEP (\$ in K)	FY19 Enacted	FY20 Request	FY20 House Mark	FY20 Senate Mark
HEP Core Program	800,000	648,038	814,000	
Line Item Construction	180,000	120,000	231,000	
<i>PIP-II</i>	<i>20,000</i>	<i>20,000</i>	<i>60,000</i>	
<i>LBNF/DUNE</i>	<i>130,000</i>	<i>100,000</i>	<i>171,000</i>	
<i>Mu2e</i>	<i>30,000</i>	
Total	980,000	768,038	1,045,000	1,065,000



P5 Implementation Status – FY 2019



All projects on budget & schedule

- ▶ Projects fully funded as of FY19
 - ▶ Muon g-2: 1st beam 2017
 - ▶ LHC detector upgrades: on track for 2019/20 installation
 - ▶ Mu2e : 1st data in 2020
 - ▶ **LSST: full science operations 2023**
 - ▶ **DM-G2 (SuperCDMS & LZ): 1st data 2020/2021**
 - ▶ **DESI: 1st light on lenses April 1, 2019**
- ▶ HL-LHC accelerator and detector upgrades started on schedule
- ▶ LBNF/DUNE & PIP-II schedules advanced due to strong support by Administration & Congress
- ▶ **CMB S4: CD-0 July 2019; developing technically-driven schedule to inform agencies, NAS Astro 2020 Decadal Survey**
- ▶ **DM-G3: R&D limited while fabricating G2**
- ▶ ILC: cost reduction R&D while waiting for decision from Japan
- ▶ Broad portfolio of small projects running or in planning (**Dark Matter New Initiative**)




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Cosmic Frontier

Cosmic Frontier Experimental Research Program

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

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

Cosmic Acceleration:

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

Dark Matter:

- Direct searches for **Dark Matter** particles with deep underground detectors
- Cosmic-ray & gamma-ray studies provide indirect searches for dark matter particles & searches for New Physics

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

Explore the unknown: search for New Physics, e.g. relic particles from the early universe

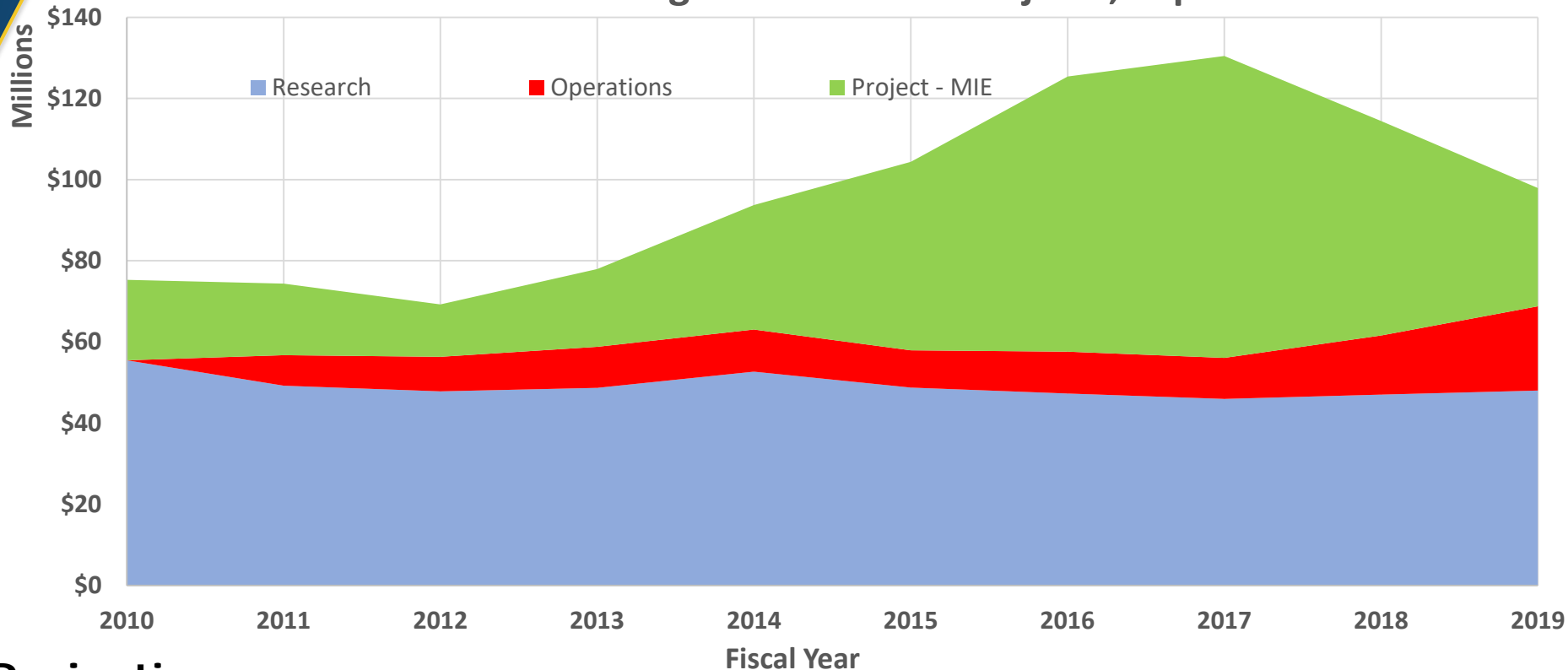
P5 Report – Cosmic Frontier

- ▶ Dark Energy (Also recommended by Astro2010)
 - ▶ Complete LSST as planned
 - ▶ Build DESI as a major step forward in dark energy science
- ▶ Dark Matter
 - ▶ Proceed immediately with a broad second-generation (G2) dark matter direct detection program with capabilities
 - ▶ Invest in this program at a level significantly above that called for in the 2012 joint agency announcement of opportunity
 - ▶ Support one or more third-generation (G3) direct detection experiments
 - ▶ Guide G3 by the results of the preceding (G1, G2) searches
 - ▶ Seek a globally complementary program and increased international partnership in G3 experiments **(DM-G3 is in the P5 plan later in later part of their 10 year plan.)**
- ▶ Cosmic Microwave Background (CMB)
 - ▶ Support CMB experiments as part of the core particle physics program
 - ▶ The multidisciplinary nature of the science warrants continued multi-agency support **(CMB-S4 Project is in P5 plan, starting ~midway through their 10 year plan.)**
- ▶ Explore the Unknown, including through cosmic rays and gamma rays



Cosmic Frontier Budget History (FY10-19)

Cosmic Frontier Program – Current Projects, Experiments



Projections:

- As the current Projects complete, estimated needs for Experimental Operations 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



Cosmic Frontier – Partnerships, Coordination, Planning

NSF and NASA partnerships on most experiments and projects

DOE-HEP, NSF-AST, -PHY, -OPP

- Full HEP Office has meetings about 2 times/year w/NSF
- Regular Joint Oversight Group (JOG) or Joint Coordination Group (JCG) meetings and close coordination of planning/issues for particular projects or experiments.
- Invited to each other's reviews, program planning, meetings.

DOE-HEP & NASA - Meetings and coordination as needed.

Three Agency Group (TAG) – DOE, NSF, NASA coordination on LSST, Euclid, WFIRST, etc.

International partners or contributions on most experiments and projects; some have private contributions

- International Resource Committees support coordination of needs & resources (FGST, LSST-DESC)
- Regular meetings with international agencies

International coordination group

- Astro-Particle International Forum (APIF) – Agency-level



Dark Energy

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

- Staged, complementary suite of surveys (in partnership with NSF-AST)
- Imaging surveys map cosmic structure over vast volumes of space
- Spectroscopic surveys build deep, 3D maps of structure and growth

Operations Completed; Data Analysis continuing:

- *eBOSS* (spectroscopic) started in 2015, ended Feb 2019 (extended)
- *DES* (imaging) started 5-year survey in late FY13, ended Jan 2019 (extended)

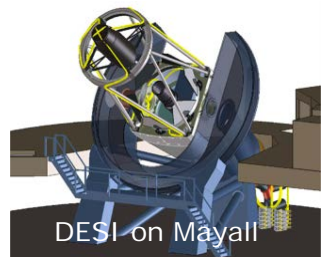
In Fabrication phase; Operations Phase and Science being planned

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

Future Planning

Cosmic Visions Dark Energy group -- Future directions to investigate optimizing science in DESI/LSST era and/or follow-on projects

- Community workshops held in 2016 at UChicago; in 2017 at LBNL
- White paper on small “enhance” efforts in Jan 2018 [arXiv:1802.07216](https://arxiv.org/abs/1802.07216);
- White Papers to Astro2020 - Massively multiobject spectroscopy, 21 cm cosmology



Dark Energy Survey

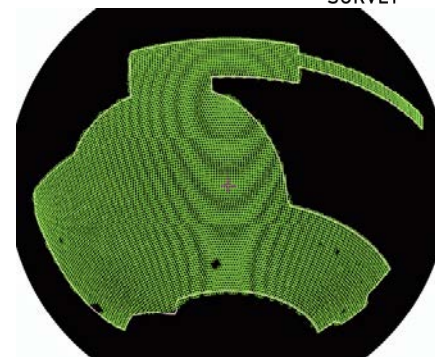


DOE-HEP partnership with NSF-AST → new camera and data systems on Blanco Telescope at CTIO

- ▶ HEP provided Camera (DECam); NSF provided data system; both participate in operations, science

Completed Observations Jan. 2019; **Met all survey metrics**

- ▶ Public Data Release “DR1” based on 1st 3 years data (Y1-Y3) has > 780 users, 6 Tb data delivered
- ▶ Completed the “Y6A1” Coadd Processing
 - ▶ 5085 sq. deg. in 5 filters (grizY), each w/ ten 90s exposures.



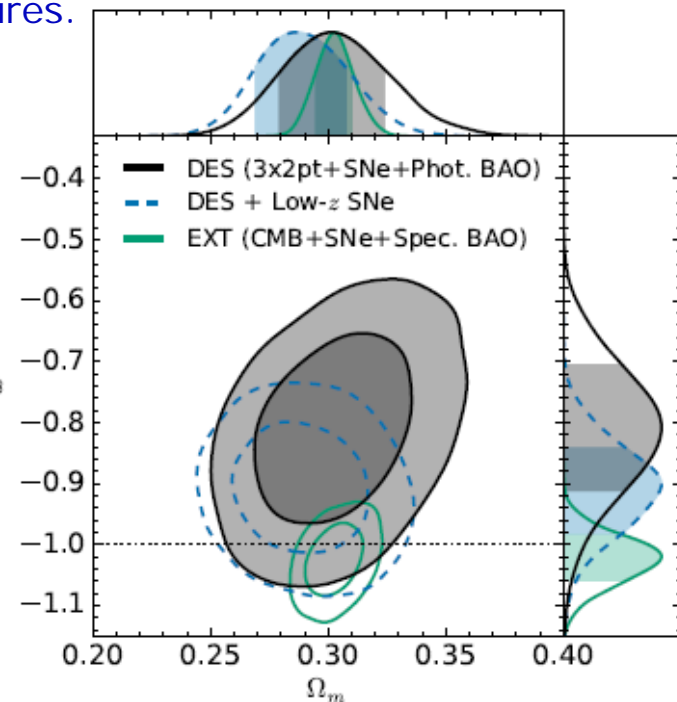
→ 243 scientific publications on range of topics (Sept. 2019)

Cosmology results:

- ▶ Constraints on Extended cosmological models from DES Y1 Weak Lensing and Galaxy Clustering (WL)
- ▶ Cross Correlation of DES WL signal w/ Planck & SPT
- ▶ Cosmology from 207 DES Y1-Y3 spect.-typed SN1a
- ▶ Combined DES Y1 WL & Y1 LSS & SN1a cosmology
- ▶ Now concentrating on Y1 galaxy cluster & Y3 3x2pt WL cosmology, with Y6 cosmological results to follow.

Many other results, from astrophysics to solar system including (recently):

- ▶ Discovery of 316 Trans-Neptunian Objects
- ▶ 1st Measurement of H_0 from a binary black hole collision
- ▶ Combined Analyses with SPTPol, BOSS, Planck, VHS, IceCube, OZDES, LIGO/VIRGO, Chandra+XMM etc.



Dark Energy Spectroscopic Instrument (DESI) - Status

DESI is an “HEP experiment” currently in fabrication phase. It will be mounted and operated on the Mayall telescope at Kitt Peak, which HEP is “leasing” from NSF

- Science: Baryon Acoustic Oscillation etc.
- LBNL is the lead lab

Project: DESI instrumentation & data management system

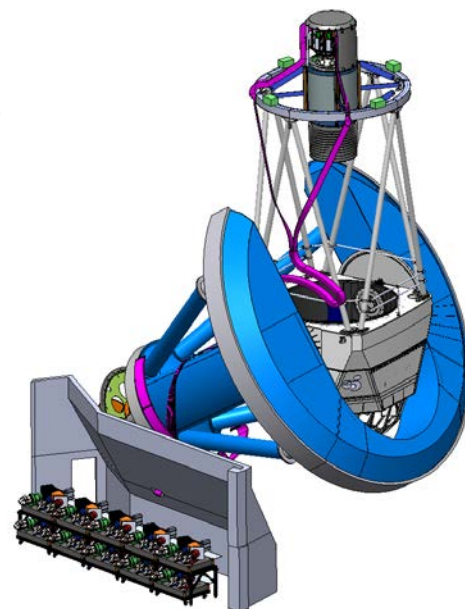
- 8 sq deg FOV, 10 3-channel spectrographs w/5000 fiber-fed robotic positioners
 - Blue: $360 < \lambda \leq 555 \text{ nm}$; $R = 2,000 - 3,200$
 - Red: $555 < \lambda \leq 656 \text{ nm}$; $R = 3,200 - 4,100$
 - Infrared: $656 < \lambda \leq 980 \text{ nm}$, $R = 4,100 - 5,000$
- All MIE project funding provided by FY19
- Installation in progress; Commissioning starts Oct. 2019
- All Deliverables complete Feb.2020; CD-4 9/21

Operations: 5 year survey

- Planning and pre-ops activities are ongoing
- HEP supporting full Mayall operations starting FY20
- Full science operations starts July 2020

Data Releases (DR):

- ▶ DESI commissioning using DR-8 (July 2019)
- ▶ DESI survey will use DR-9 (December 2019)



DESI - Status

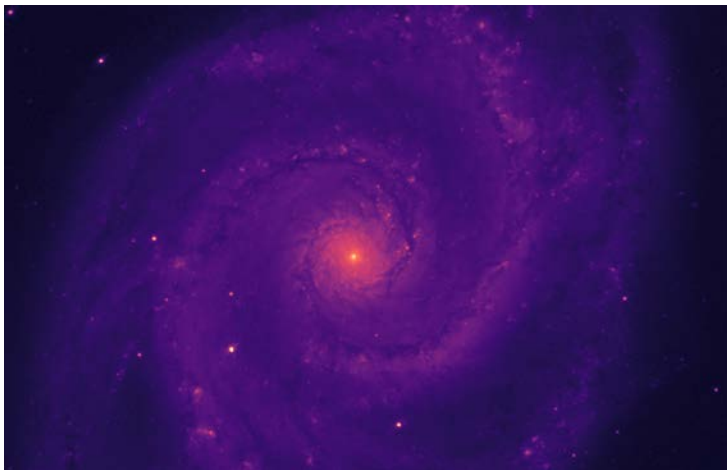
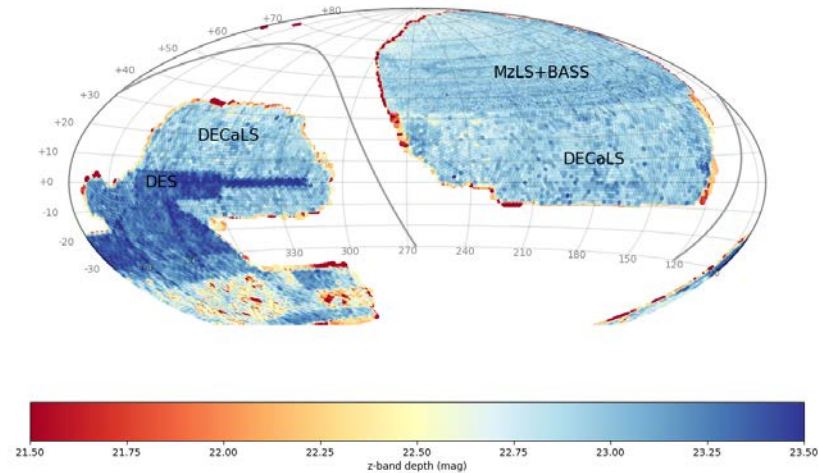
All imaging surveys for target selection completed

Have coordinated 3 observing sites over the past 5 years

- Mayall Telescope 401 nights
- Bok Telescope 300 nights
- Blanco Telescope 203 nights

Final footprint 16,000 sq deg in northern sky

- ▶ (exceeds DESI requirement of 14,000 sq deg)

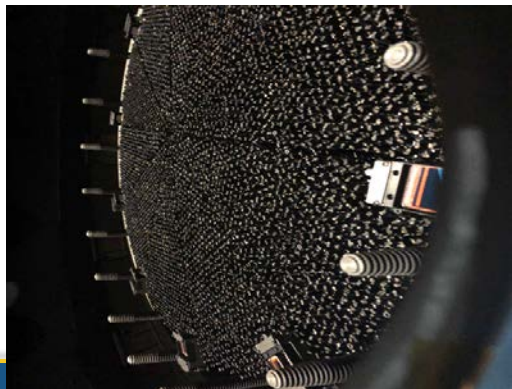


**First light on corrector lenses
(4/1/19); Whirlpool galaxy as
seen by commissioning
instrument**



DESI is being installed at the Mayall 4-m Telescope at Kitt Peak, Arizona – WOW!

Sept. 2019: All 10 petals with 5000 fiber-fed robotic positioners have been installed in the barrel & 6 of 10 spectrographs have been installed.



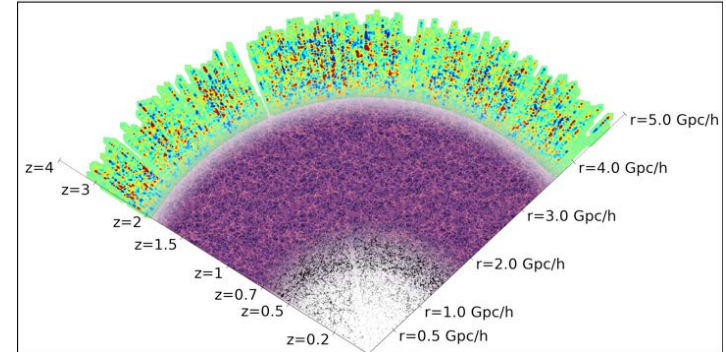
DESI: The first Stage-IV Dark Energy Experiment

When DESI turns on, it will be the most powerful multi-object spectrograph on the planet. Its 5-year survey will measure spectra from:

- ▶ 2.4 million QSO's
- ▶ 17 million ELG's
- ▶ 14 million LRG's
- ▶ 10 million brightest galaxies

DESI will measure the distance scale from BAO:

- ▶ 0.28% precision from $0 < z < 1.1$
- ▶ 0.39% precision from $1.1 < z < 1.9$
- ▶ Measure the Hubble Parameter to 1.05% at $1.9 < z < 3.7$ from BAO
- ▶ Dark Energy Equation of State
- ▶ Plus, limits on neutrino masses, modified gravity, inflation, etc...



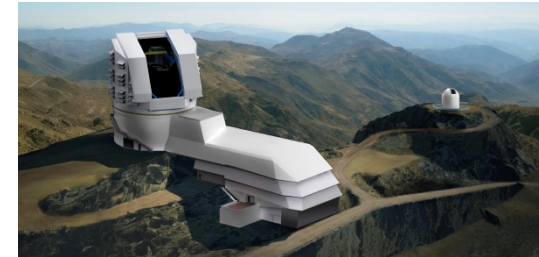
Surveys	FoM	σ_{wp}	σ_{Ω_k}
BOSS BAO	37	0.055	0.0026
DESI 14k galaxy BAO	133	0.023	0.0013
DESI 14k galaxy and Ly- α forest BAO	169	0.022	0.0011
DESI 14k BAO + gal. broadband to $k < 0.1 \text{ hMpc}^{-1}$	332	0.015	0.0009
DESI 14k BAO + gal. broadband to $k < 0.2 \text{ hMpc}^{-1}$	704	0.011	0.0007

Large Synoptic Survey Telescope (LSST)

DOE-HEP & NSF-AST partnership, currently in its Construction phase.

→ **1 project, 2 agencies** w/international, private contributions

- **NSF is the lead Agency.**
- **SLAC** is the DOE lead lab & carries out responsibilities
 - Significant efforts by BNL, LLNL, universities

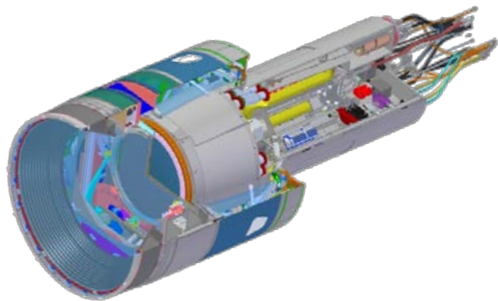


Construction Project: NSF/DOE MOU in 2012

New state of the art observatory facility in Cerro Pachon in Chile

NSF: 8m wide-field Telescope & Site (T&S), Data Management (DM), EPO

DOE: 3.2 giga-pixel Camera



Camera:

- All MIE funding provided by FY18, TPC \$168M
 - MIE completes when Camera is integrated and tested at SLAC; estimate January 2021, Critical Decision 4 (CD-4) milestone is March 2022.
- Camera integration and commissioning with T&S and DM system in Chile is supported on HEP program funds; lined up with NSF's MREFC to complete at end of FY2022.

Large Synoptic Survey Telescope (LSST)

Facility Operations

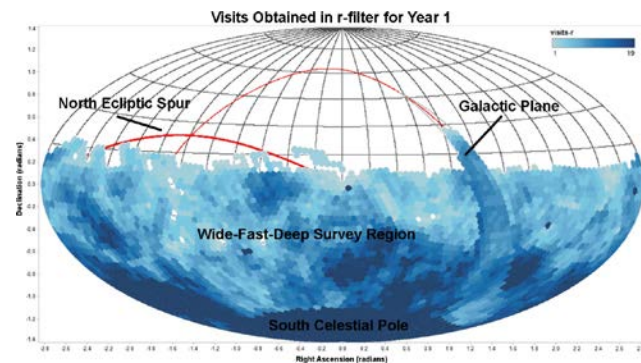
The LSST facility will conduct a 10-year deep, wide, fast, optical imaging survey of more than 37 billion objects

May 2019: DOE and NSF agree to provide support for Operations. International in-kind contributions in exchange for data rights/access will be approved by the agencies.

- Pre-operations planning and activities have started
- Full science operations at start of FY2023.

Agency Oversight and Reviews:

- Weekly NSF/DOE Joint Oversight Group (JOG) meetings
- Joint reviews of Project and Facility Operations plans



Scientific Research - Both NSF and DOE will support community efforts

- DOE's research efforts are organized through Dark Energy Science Collaboration (DESC); planning activities are continuing



LSST Dark Energy Science Collaboration (DESC)



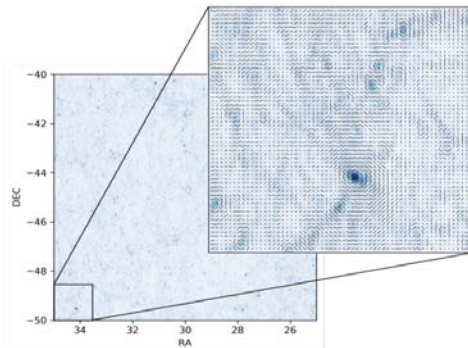
www.lsstdesc.org

- Set up to carry out planning, preparations and eventual data analysis to support HEP science goals for precision dark energy analyses
- Operations Plan review held May 2018; planning continues.

As of July 2019, the collaboration has 949 Members and 215 Full Members.

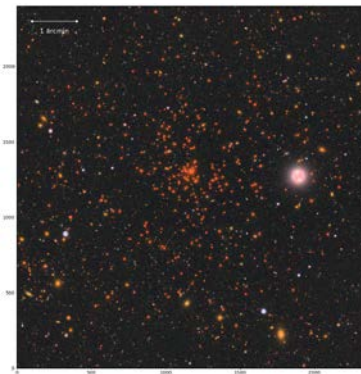
- *Full Members have committed a significant fraction of their research time to the DESC, and have voting rights.*

Updates since June 2019:



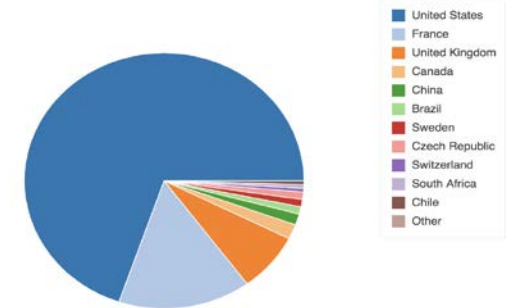
[Public release](#) of CosmoDC2, a state-of-the-art extragalactic catalog that can be used to test cosmological analysis methodology

15 DESC papers published or submitted in 2019 so far. DESC is actively preparing for cosmological analysis with LSST!



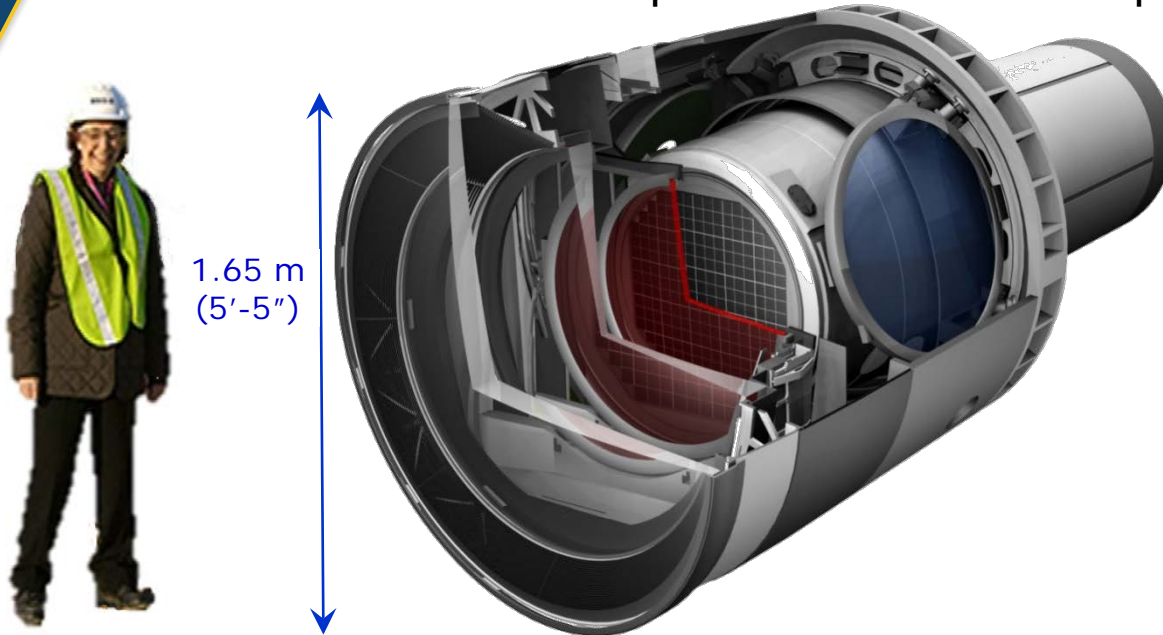
DESC's image simulations may help LSST Operations practice serving LSST data to the broader science community.
(Image credit: Dominique Boutigny)

Full Members by Country



LSST Camera – Awesome!

Enormous **Camera** to exploit the wide 9.6 sq deg field of view (FOV)



The 3.2 Gigapixel LSST Camera will be the largest electronic camera ever built for ground-based astronomy.

- The world's largest high-performance optical lens ever fabricated
- Six optical filters, five of which are resident in the camera on any given night.

3.2 GigaPixel Camera

- 63 cm focal plane
- 2 second readout (fast!)
- 3060 kg
- 1.57 M front Lens
- 6 filters 0.3 – 1.1 μ

LSST Camera Project Status

L1-L2 at SLAC



- All Sensors have been received and assembled and science rafts, which have been fully delivered from BNL
- 9 science rafts and 4 corner rafts have been integrated into the cryostat

L1-L2 lens assembly from LLNL/vendor shipped to SLAC successfully; L3 lens finished and will be shipped soon



Focal plane integration



Refrigeration heat exchanger on the cryostat



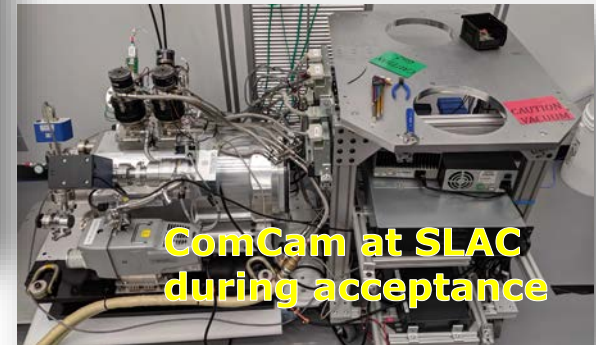
Filter Changer (France)



Camera clean room on the summit

Camera commissioning effort started in Chile - auxiliary room and camera clean room

Commissioning Camera (ComCam) focal plane delivered to LSST Project



ComCam at SLAC during acceptance

Cosmic Microwave Background

Gain insight into **inflationary epoch, dark energy, neutrino properties, searches for relic particles, and new physics** by studying the oldest visible light.

Operating Experiments:

SPT-3G (*NSF-led, with HEP participation*) – HEP provided support for major upgrade of the camera to greatly increase sensitivity; HEP participates in Operations which started Feb 2017



HEP Efforts:

- Research efforts on many experiments – ground, Planck
- DOE/NERSC computing making major contributions to many ground-based experiments & Planck.
- Following the 2014 P5 recommendation, advanced detector and readout technology R&D and concept planning ramped up in preparation for CMB-S4.

South Pole Telescope Generation 3 (SPT-3G)

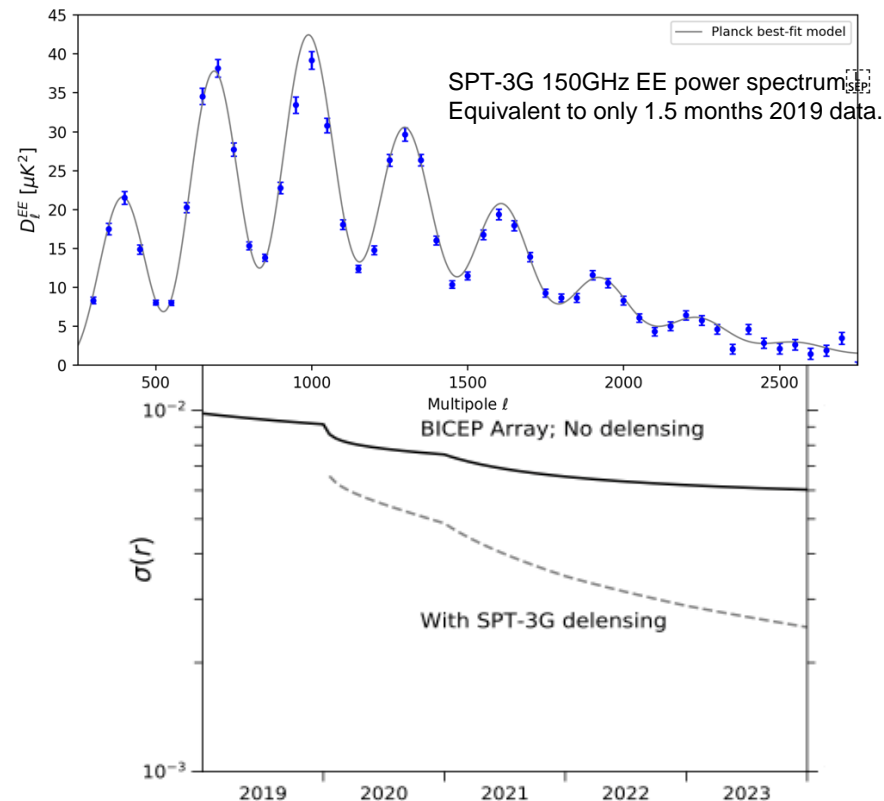
SPT-3G → Third-generation Receiver for the South Pole Telescope

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

- fabrication of 16,000-detector SPT-3G focal plane (led by Argonne National Lab), major upgrade of the camera to greatly increase sensitivity
- Operations: commissioning 2017; science ops started 2018

1500-deg² survey going extremely well.

- ▶ Final 5-year data set will be unprecedentedly deep at arcminute angular scales: projected map noise of 2.2 μK -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 $\sigma(r) \sim 0.0025$. Without the SPT-3G data, the r limit would be limited by lensing B mode polarization at over a factor of two higher.



Cosmic Microwave Background Stage 4



Early 2010's: CMB-S4 Community-based Collaboration brought together ground based community to plan future; *CMB-S4 Collaboration Science, Technology Books*:

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

2014: P5 recommended HEP participation with NSF in CMB-S4, starting in middle of P5 decade.

- CMB science is a priority in all funding scenarios; Significant HEP community interest

- 2015: HEP labs/community ramped up efforts on technology R&D and concept planning to align with P5.
- HEP moved forward in planning, in coordination with NSF-AST/OPP/PHY

2016: Science collaboration established

- DOE & NSF charged AAAC subpanel: Concept Definition Taskforce (CDT)

2017: CDT report provided science goals, initial strawperson concept design, cost, and schedule

2018: pre Project Design Group (pPDG) established by DOE labs to focus on project development and coordination, and getting to Critical Decision 1.

Project/Activity	Scenarios			Science Drivers				
	Scenario A	Scenario B	Scenario C	Higgs	Neutrinos	Dark Matter	Cosm. Accel.	The Unknown Technique (Frontier)
Medium Projects								
LSST	Y	Y	Y		✓		✓	C
DM G2	Y	Y	Y			✓		C
Small Projects Portfolio	Y	Y	Y		✓	✓	✓	All
Accelerator R&D and Test Facilities	Y, reduced	Y, some reductions with reduction to PIP-II development	Y, enhanced	✓	✓	✓	✓	E,I
CMB-S4	Y	Y	Y		✓		✓	C
DM G3	Y, reduced	Y	Y			✓		C
PINGU	Further development of concept encouraged				✓	✓		C
ORKA	N	N	N					I
MAP	N	N	N		✓	✓	✓	E,I
CHIPS	N	N	N		✓			I
LAr1	N	N	N		✓			I

- CMB-S4 is the last remaining project recommended by P5 for HEP to now implement
- Planned as the HEP flagship Cosmic Frontier fabrication project in 2020s

CMB-S4 Planning Status (2019)

➤ CMB-S4 project continuing preparation

Formed Integrated Project Office (IPO) – under Jim Yeck

- Refine cost, plan for detectors, concept & layout of scope
- Detector fabrication & readout issues at the forefront of R&D/planning - No new technology, but scale-up needed.

➤ CMB-S4 collaboration progress

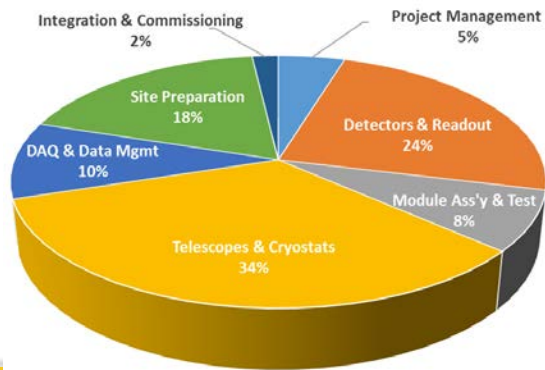
- July submission to NAS Astro2020 Decadal Survey

➤ IPO and Collaboration work together to plan concept with technically driven schedule; submission of plans to Astro2020, agencies, etc.

➤ Interagency (NSF-DOE) Joint Coordination Group (JCG) meeting bi-weekly to share information, monitor, and review.

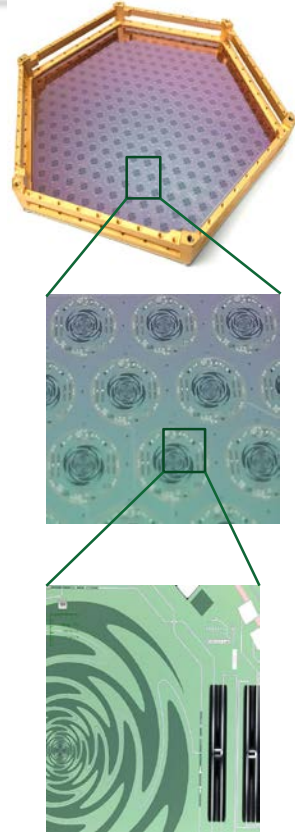
- HEP, NSF-AST, NSF-OPP, NSF-PHY

Dec.2018 IPO held concept review
Aug.2019 HEP-charged review of sensor fabrication plans



At DOE:

- Critical Decision 0 (CD-0) "Mission Need" was approved by Office of Science Leadership in July 2019. **PROJECT START!**
- HEP working w/IPO & funding near term R&D, concept planning (FY18, FY19 funds provided)



Axion Dark-Matter eXperiment Generation 2 (ADMX-G2)

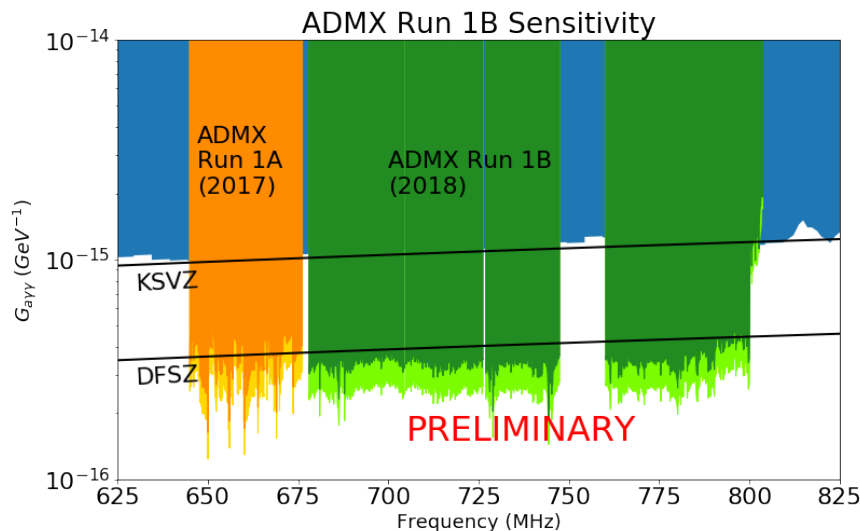
ADMX-G2: Located at University of Washington, managed by Fermilab

- Primarily DOE supported with contributions from the UK, Germany and Australia; R&D support from the Heising-Simons Foundation
- Uses a strong magnetic field and resonant cavity to convert dark matter axions into detectable microwave photons

Operating: Runs covering range 0.5 to 2 GHz (~ 2 to 8 micro-eV mass) started Aug. 2016; complete ~ Jan. 2022

Run 1A (2017) & **Run 1B** (2018) – both reached “invisible” axion (DFSZ model) sensitivity!

Run 1C commissioning; **Run 2** Cavities under development



LUX - ZEPLIN (LZ) Experiment

LZ is an HEP experiment (led by LBNL) currently in fabrication phase. It will be located nearly 1 mile underground in the Sanford Underground Research Facility (SURF) in Lead, SD.

- **Physics:** Direct detection of WIMPS, dual phase liquid Xe; sensitivity $\leq 2 \times 10^{-48} \text{ cm}^2$, close to where astrophysical neutrinos become an irreducible background.
- **Partnership:** International and private contributions including from UK, Korea, Portugal, SDSTA, Russia

Project: TPC with 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.

- All MIE project funding provided by FY19
- Installation in progress; Commissioning starts Oct. 2019
- All Deliverables complete July 2020; CD-4 3/22

Operations: Planning and pre-ops activities are ongoing.

- Full 5-year science operations starts ~ Aug. 2020



March 2019 Operations
Plan review at SURF



Sept. 2019: TPC assembled, then inserted into inner cryostat vessel.

Super Cryogenic Dark Matter Search at SNOLAB (SuperCDMS SNOLAB)

SuperCDMS is an HEP, NSF/PHY experiment, with contributions from Canada (CFI, NSERC), currently in fabrication phase (led by SLAC). It will be located 2km underground at SNOLAB, Sudbury, Canada.

Science: Direct detection of WIMPs, with extended sensitivity to very small energy depositions, enabling additional searches for axions, lightly ionizing particles, and electron-recoil dark matter interactions. Lower mass (complementary to LZ)

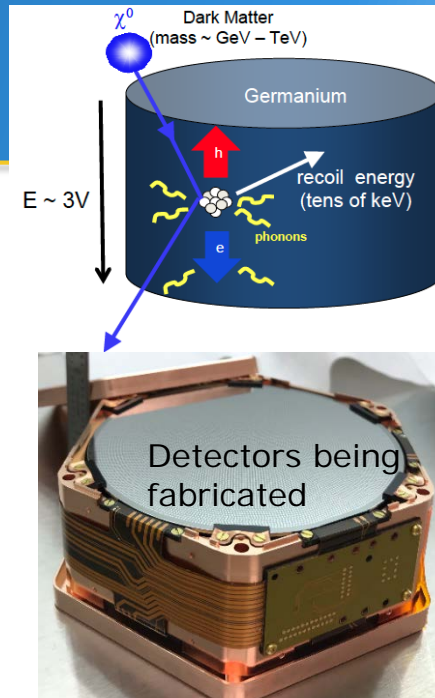
Project: Detector uses cryogenic germanium and silicon crystals with sensors that detect ionization and phonon signals.

- All MIE project funding provided by FY19, Installation 2019-2020
- All Deliverables complete Sept.2020; CD-4 9/21

Operations: Planning and pre-ops activities are ongoing. Full science operations starts in FY2021.



Trial assembly of lead shielding
at Lerner-Pax in France



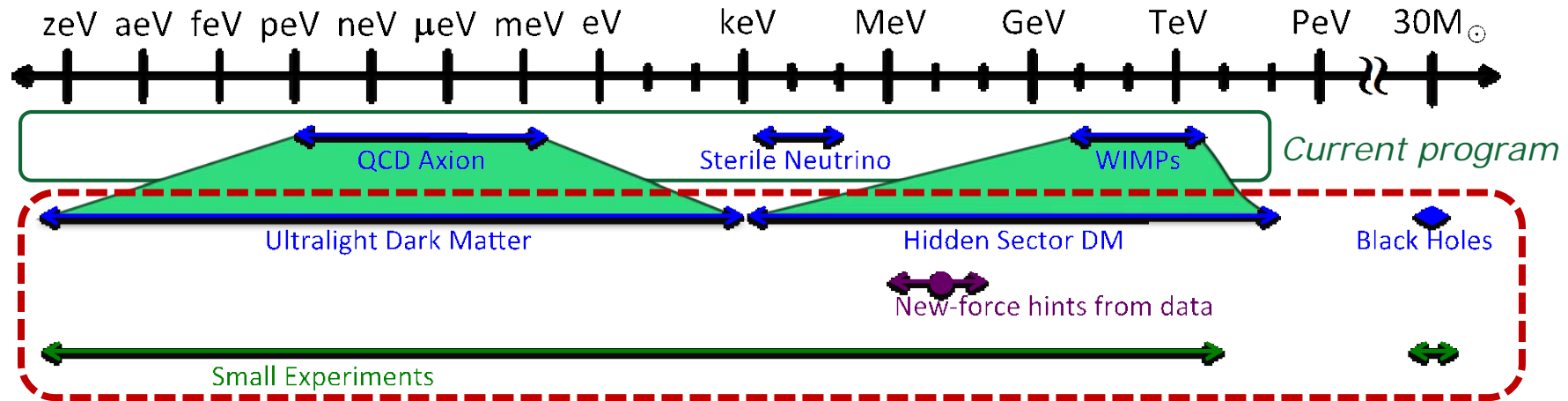
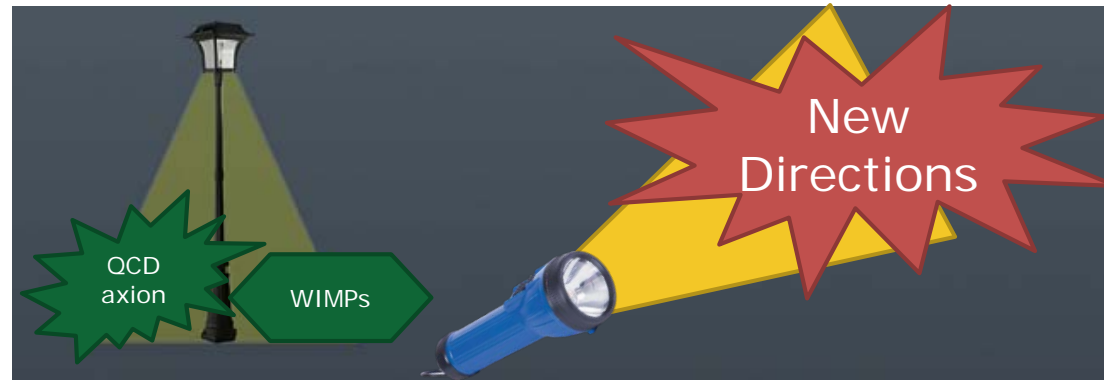
Infrastructure installation proceeding
in Ladder Lab at SNOLAB

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



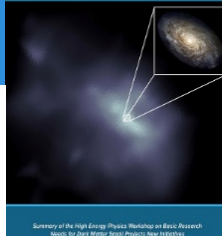
New Directions in Dark Matter



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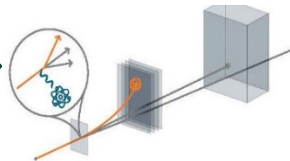
New Initiatives in Dark Matter



P5 recommended the search for dark matter particles as a high priority & program should include small projects. The initiative follows recent theoretical advances plus recent development of new technologies

- ▶ March 2017: Community-led workshop collected new ideas, <https://arxiv.org/abs/1707.04591>
- ▶ January 2019: Basic Research Needs study: <https://science.osti.gov/hep/Community-Resources/Reports>
 - Assessed the science landscape for dark matter particle searches and identify high impact science areas suitable to be pursued with small projects in the HEP program, using DOE lab infrastructure & capabilities → Identified 3 priority Physics Research Directions (PRD)
 - **Develop the case(s) for additional HEP funding to support such new initiatives in the future.**
- ▶ **2019/20: Review & fund proposals for concept designs and near term technology development.**
- ▶ Later: Select concept(s) for fabrication (possibly in stages)

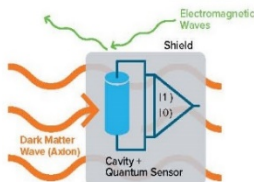
PRD 1
Create and
Detect DM at
Accelerators.



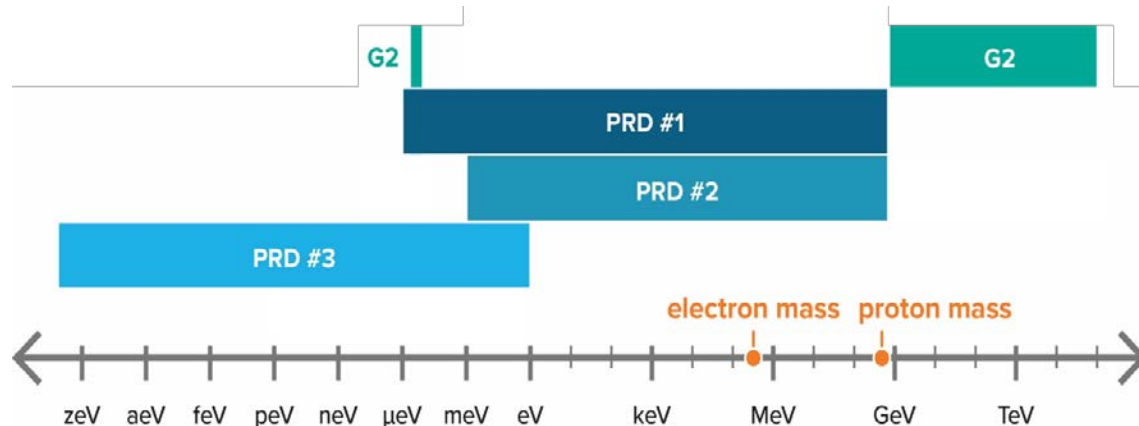
PRD 2
Detect Galactic
DM Underground.



PRD 3
Detect Wave
DM in the
Laboratory



Continue to support theory studies, research efforts, tech. R&D as necessary and appropriate



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

→ 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 as operations continue past 10 years

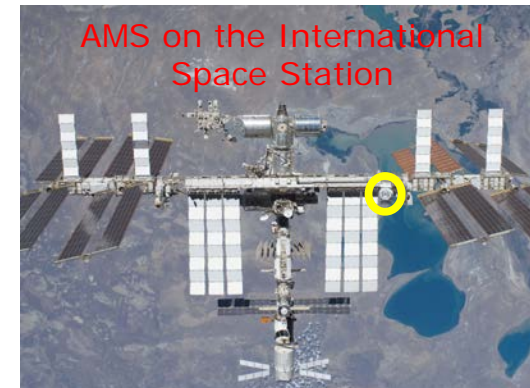
AMS (w/NASA)

- ▶ Operations continuing on ISS

HAWC (w/NSF)

- ▶ 5 year operations started early 2015

Lower program priority for new experiments

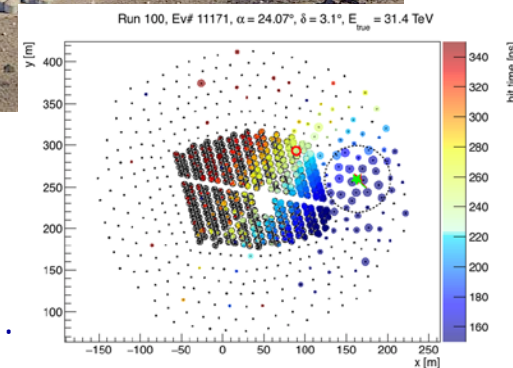
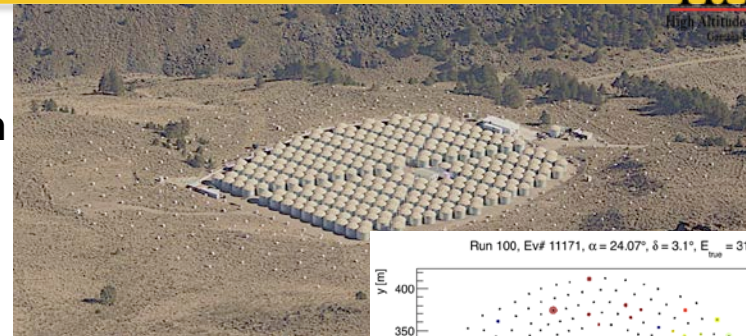


High Altitude Water Cherenkov (HAWC)



HAWC gamma/cosmic-ray observatory located on the Sierra Negra mountain in Mexico: Water Cherenkov Air Shower Detector, now with Outrigger

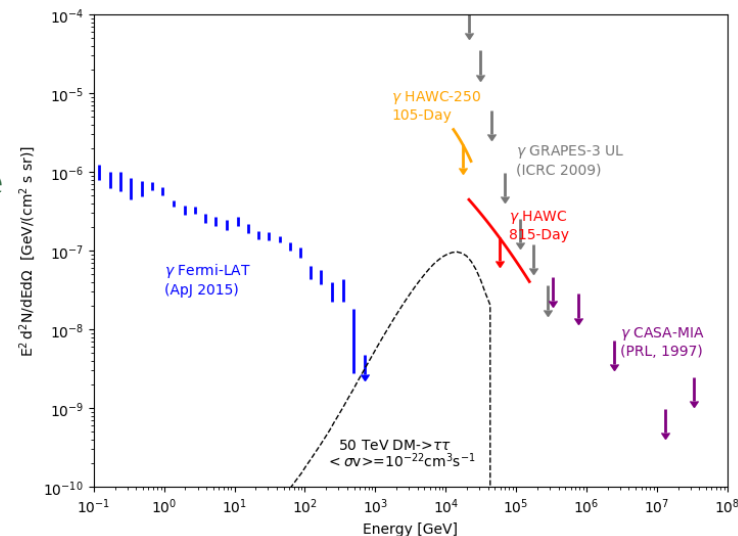
- ▶ 5 year ops. started early 2015
- ▶ Partnership with NSF-PHY, Mexico



Science: All sky γ -ray survey 100 GeV to > 100 TeV; Wide FOV and high energy sensitivity places limits and constrains: dark matter cross sections, origin of high energy neutrinos detected by IceCube; highest energy e^- in solar neighborhood.

Recent Results: Limits on the Diffuse High Galactic Latitude γ -ray emission due to sources:

- Unresolved extragalactic objects such as active galactic nuclei,
- Isotropic Galactic gamma-rays
- Possible emission from dark matter annihilations or decays in the Galactic dark matter halo



Fermi Gamma-ray Space Telescope: Large Area Telescope Collaboration

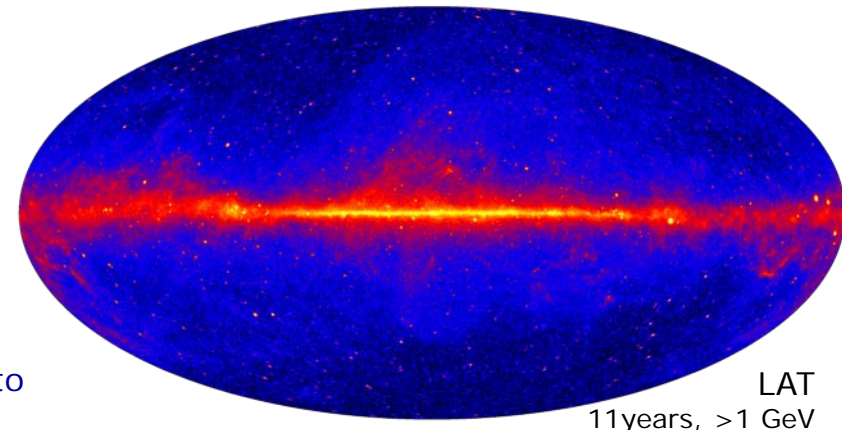
LAT Partnership:

- DOE HEP partnered with NASA on fabrication of the LAT at SLAC, together with international contributing countries: France, Italy, Japan, Sweden.

Science: Study high-energy (~ 20 MeV- >300 GeV) gamma-rays using particle physics detector technology in space. Indirect Dark Matter (DM) detection; high-energy acceleration mechanisms, etc.

Status:

- Launched June 2008 for 5-year mission with 10-year goal
- Operations: HEP is supporting efforts at the Instrument Science Ops Center at SLAC; in coordination with NASA, HEP is planning to continue support of critical efforts at SLAC as operations continue past 10 years.
- 2019 July 17: NASA extended the *Fermi* mission through FY22 based on the 2019 Senior Review, and invited *Fermi* to propose for the next Senior Review in 2022.



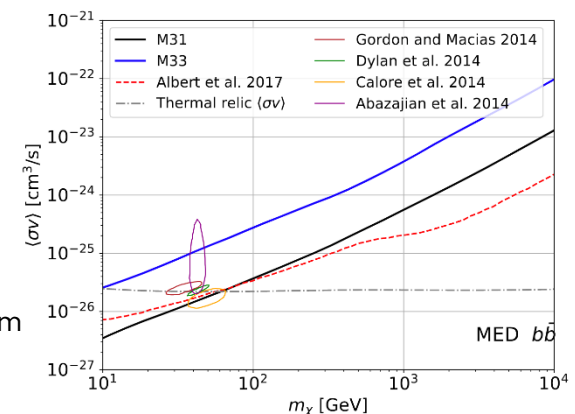
Science Results

As of September 2019, nearly 600 papers published.

Recent results include:

- Competitive limits on DM annihilation based on LAT detection of Andromeda (M31, which has a large γ -ray contribution from pulsars and interstellar diffuse) and non-detection of Triangulum (M33) ([Di Mauro et al. 2019, PRD, 99, 123027](#)).

Dark matter limits from
Local Group galaxies
M31 & M33



Other HEP Efforts related to Cosmic Frontier

Theory program

- Vibrant Theory Program supporting all areas including [Cosmic Frontier](#); QIS actively growing area; Support for Theory centers and groups at several universities and labs.

Advanced Detector Development program

- ▶ Active R&D developing next generation detectors, including CCDs, TES superconducting bolometers, MKIDs, readout electronics, optics. [Key elements for DES, LSST, CMB-S4](#). Important impact on X-ray detector, medical detectors.

Computational HEP program

- Coordinates DOE Supercomputer allocations via various ASCR and DOE Competitions
 - ▶ Cosmic Simulations, Emulators, Data Analysis
 - ▶ Computational HEP, SCIDAC – focused computational challenges
 - ▶ HEP Center for Computational Excellence
- High Performance Computing – Comp HEP & ASCR coordination & partnerships on some efforts, including [Cosmic Simulation and Data analytics](#)
- Manages allocations on NERSC facility for HEP Cosmic Frontier Simulations and Experiments

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
- ▶ **FY2020 Budget Request** includes funds in HEP, BES (Basic Energy Sciences), and ASCR (Advanced Scientific Computing Research) for at least one jointly-supported and multidisciplinary QIS Center, as per the National Quantum Initiative Act (Dec 2018)

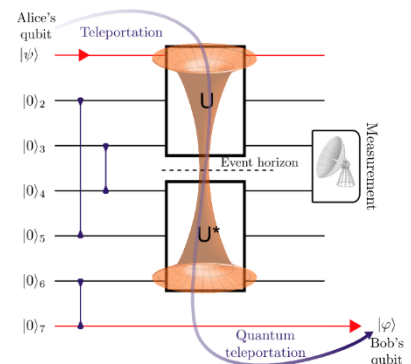
Quantum Information Science Enabled Discovery (QuantISED) for High Energy Physics

Powerful new windows to accomplish HEP mission & advance QIST Foundational theory, computing, sensors, technology, experiments -- Partnerships with DOD, NIST

Examples:

- Cosmos and Qubits: Foundational concepts and mathematical formulations that explore black hole physics and how black holes scramble information lead to new ways to study how qubits stabilize in the laboratory & fault tolerance. Simulating worm holes/study of teleportation protocols... See <https://www.nature.com/articles/s41586-019-0952-6>
- Accelerator cavities adopted for quantum regime: Record high photon lifetimes achieved at Fermilab in 2017-2018 → seconds of coherence after targeted treatment
- Sensor studies – many will enable dark matter searches over a wide mass range.

→FY2020 Budget Request includes funds in HEP, BES (Basic Energy Sciences), and ASCR (Advanced Scientific Computing Research) for at least one jointly-supported and multidisciplinary QIS Center, as per the National Quantum Initiative Act signed into law in December 2018



HEP Computing Challenges

- P5 recommended a program of challenging scientific experiments that have equally challenging computing needs
 - As an example, in FY2019 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
- The HEP Computing Infrastructure Working Group was formed in 2017 to develop a strategy for meeting the computing needs. ([See talk at HEPAP, 5/31/19](#))
- Successfully addressing computing challenges will require continued effort from the community and coordination with ASCR and NSF's Institute for Research and Innovation in Software for High-Energy Physics (IRIS-HEP) which is tackling similar issues from the university perspective





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AAAC Report – April 2019

AAAC Report 2018-19 (DOE specific)

Recommendation #5

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 source code to create the data products in order that the community can learn how those data products were created. We are aware that support for continued use of the source code is a much larger endeavor, and the additional benefit of such support is not clear at this time. Agencies should include in survey budgets funding to enable adequate public access to the data, software, and data products of these surveys.

Response:

All current and planned surveys supported by DOE/Cosmic Frontier have approved data management plans that are consistent with the AAAC Principles of Access and the DOE Office of Science Statement on Digital Data Management. Many experiments provide software in their public data releases to access and analyze the data products. The data management system is developed as part of the project and experimental operations plan and covered in the relevant budgets. Current projects and experiments may not have plans or available funds to provide full access tools; this will be important going forward with new projects being developed.



AAAC Report 2018-19 (DOE specific)

Recommendation #6

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 surveys, 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:.

Every DOE-HEP experiment carried out in partnership with another agency has a Joint Coordination Group, Joint Oversight Group, or similar to coordinate public releases of data sets, data products, data access tools, and related software.



AAAC Report 2018-19 (DOE specific)

Recommendation #11

We continue to recommend that the three agencies either broaden the current discussions or create parallel discussions to consider broadly the costs and benefits of coordination on the science areas of interest to both the Euclid and LSST communities. We recognize that if a decision is made to plan for coordination between LSST and Euclid during construction of LSST and to execute such a plan during LSST operations, the budgets for both the construction and operation of LSST would likely need an augmentation.

Response:

DOE-HEP is engaged in LSST for the dark energy science, primarily carried out through the Dark Energy Science Collaboration (DESC). HEP coordinates on LSST and related experiments' dark energy science with NSF-AST and NASA through the Tri-Agency Group and other communications. DOE-HEP is not engaged in Euclid nor WFIRST.

The LSST Project is carrying out a specific scope on a budget and schedule and did not include coordination of data with other projects. However, scientific efforts to coordinate the data with other surveys can be considered for support, and some studies are already being carried out.



AAAC Report 2018-19 (DOE specific)

Recommendation #31

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 LSST.

Response:

The Facility Operations plan for LSST is in the process of being developed and will be optimized within the overall portfolio to ensure opportunities for the science community that take into account the investments.



AAAC Report 2018-19 (DOE specific)

Recommendation #38

DOE-HEP should continue to pursue searches for alternatives to the standard dark matter candidates.

Response:

Following the DOE Basic Research Needs process, DOE-HEP released Funding Opportunity Announcement DE-FOA-0002112 on Dark Matter New Initiatives. FY2019 support is planned for several proposed efforts to develop project concept designs and execution plans. These awards will be posted on our [www](http://www.doe.gov) site when made public.



AAAC Report 2018-19 (DOE specific)

Recommendation #57

The AAAC urges Congress to increase the proposed FY 2020 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 from the numerous world-class facilities currently nearing completion.

Response:

This recommendation is for Congress. The House and Senate marks are above the Administration request. The FY20 budget has not yet been enacted.





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**Grants, Funding
Opportunities**

Research Support - Priorities

Research budgets: Support scientists on **all phases** of an experiment (design/build/operate)

Priority – to support effort to plan and carry out **priority science topics** on our experiments, i.e. need to make sure the science it was designed for is carried out!

- Support research efforts directly in line with program & project priorities, responsibilities & science goals
- Distribution of efforts across areas will necessarily change to support changing priorities
- Sufficiently support the [Science Collaborations](#) (HEP model) to carry out experiment in all phases - project's design, fabrication and operations & to plan and carry out data analyses to deliver the best science

Priority Areas:

Dark Matter :

Construct and plan G2 experiments; modest future R&D

Dark Energy :

DES analysis; construct and plan LSST and DESI

CMB: Begin planning for CMB-S4

Not funded in our program: Support for gravitational waves, astronomy, planet searches, ions, AMO, etc.



Funding Opportunities

Research Opportunities in High Energy Physics (“Comparative Review”)

- ▶ Main funding source for university grants; FOA typically out in the fall

Workforce Development (WDTs) programs: <https://science.energy.gov/wdts/>

- ▶ Office of Science Graduate Student Research fellowships (SCSGR)
- ▶ Science Undergraduate Laboratory Internships (SULI)
- ▶ Visiting Faculty Program

US-Japan

- National Lab Program Announcement (NLA): *“US-Japan Science and Technology Cooperation Program in High Energy Physics”* for the US-Japan cooperative R&D program
- US-Japan Student Exchange Program

Accelerator Science

- **2019 Research Opportunities in Accelerator Stewardship**
Supports basic accelerator research of broad benefit; conducted with 11 federal agencies
- **2019 DOE Traineeship in Accelerator Science & Engineering:** Student support

Quantum Information Science Enabled Discovery

Dark Matter New Initiatives (2019): Project design & near-term tech R&D aligned w/Physics Research Directions in the Basic Research Needs report

Office of Science

- ▶ **Early Career Research:** <https://science.energy.gov/early-career/>
- ▶ **SC “General” [always open]** - HEP uses this primarily for conferences and unforeseen circumstances (e.g. equipment failure)

HEP Research Grant Statistics

– Cosmic Frontier

		FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19
Cosmic \$M request Y1-3		\$3.30	\$7.70	\$7.50	\$6.80	\$7.80	\$24.60	\$27.61	\$18.28
Cosmic \$M request Y1		\$3.30	\$7.70	\$7.50	\$6.80	\$7.80	\$7.60	\$14.32	\$5.22
Cosmic \$M funded Y1		\$1.60	\$3.40	\$4.4 w/FFF	\$3.3 w/FFF	\$4.3M w/FFF	\$4.7M w/FFF	\$5.4M w/FFF	\$3.4M w/FFF
Cosmic - proposal counts									
	Received	11	33	29	27	43	31	30	23
	Reviewed	10	28	28	27	36	26	28	20
	Funded	6	18	19	14	21	18	23	17
	Success rate	60%	64%	68%	52%	58%	69%	82%	85%
Cosmic CR - PI counts									
	Received	21	61	40	43	65	49	56	36
	Reviewed	20	54	38	43	55	43	54	33
	Funded	13	27	25	21	25	26	38	27
	Success rate	65%	50%	66%	48%	45%	60%	70%	82%

Early Career Awards – Cosmic Frontier

FY19:



Tim Eifler
Dark Energy



Scott Hertel
Dark Matter



Elisabeth Krause
Dark Energy

Crosscutting programs



Cora Dvorkin
CMB theory



Peter Sorensen
Dark Matter detectors

FY18:

Crosscutting programs



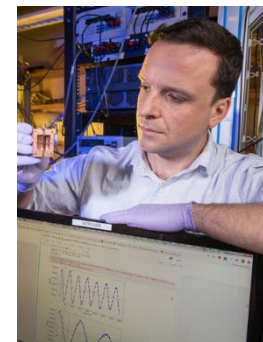
Alexie Leauthaud
Dark Energy



Hee-Jong Seo
Dark Energy



Aritoki Suzuki
CMB detectors



Daniel Bowring
Dark matter QIS



Benjamin Safdi
Dark matter theory

Early Career Statistics – Cosmic Frontier

	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19
# received - Univ	11	8	12	16	6	7	7	8	11	13
# received - Lab	10	4	7	9	7	5	6	5	5	4
# funded - Univ	2	1	2	1	1	0	1	1	2	3
# funded - Lab	0	2	1	1	0	0	0	1	0	0

2019 HEP PI Meeting

- ▶ The 2019 HEP University PI Meeting took place in parallel to the APS DPF 2019 Meeting
- ▶ 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



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

DPF2019
July 29-August 2
Northeastern University
Boston, MA
dpf2019.northeastern.edu

APS DIVISION OF PARTICLES & FIELDS

Northeastern College of Science

Photo by Matthew Modomo/Northeastern University

Program Committee:

Emanuela Barberis (Northeastern U.) Co-Chair	Mirjam Cvetič (U. of Pennsylvania)	Bo Jayatilaka (INM)	Steven Ritz (U. of California Santa Cruz)	Stefan Söldner Rembold (U. of Manchester)
Toyoko Oritani (Northeastern U.) Co-Chair	André de Gouvêa (Northwestern U.)	Young-Kee Kim (U. of Chicago)	Kate Scholberg (Duke U.)	Tim Tait (U. of California Irvine)
George Alverson (Northeastern U.)	Dmitri Denisov (FNAL)	Rafael Lang (Purdue U.)	Louise Skinnari (Northeastern U.)	Stephane Willocq (U. of Massachusetts Amherst)
Priscilla Cushman (U. of Minnesota)	Hassan Jawahery (U. of Maryland)	Michael Peskin (SLAC)	Marcelle Soares-Santos (Brandeis U.)	Darlen Wood (Northeastern U.)

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.

Cosmic Frontier News:

- DESI and LZ start operating in 2020.
- CD-0 has been approved for CMB-S4.
- LSST Project is being carried out; LSST Facility Operations details are being planned.
- Dark Matter small project designs starting development.



Significant planning for the future – looking forward to Astro2020 for exciting opportunities & directions!





U.S. DEPARTMENT OF
ENERGY

Office of
Science