U.S. DEPARTMENT OF ENERGY | Office of Science

Office of High Energy Physics (HEP) Report

Astro2020 Panel on An Enabling Foundation for Research

October 22, 2019

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OUTLINE

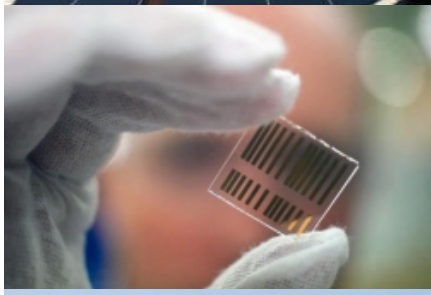
- DOE, SC, HEP Mission
- Program Guidance, Planning, Execution, Partners
- HEP Budget
- Cosmic Frontier Program, Budget
- Cosmic Frontier Research
- Related Efforts

Total Solar Eclipse over Cerro Pachon, July 2, 2019
Photo: K. Reil LSST/DOE/SLAC

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 (SC) 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 US

- Science leadership & support to enable significant advances in specific areas
- Develops & supports a portfolio of facilities & experiments to obtain the science
- **Laboratory System** provides comprehensive resources and infrastructure to design, build, operate selected facilities & projects & tech R&D
- Interagency & International partnerships leverage additional science & expertise

<u>The Mission emphasis translates into management of the 6 SC programs</u>

- Extensive use of community peer review & federal advisory committees to develop science directions for research investments, identify priorities and select the very best scientific proposals to support to obtain significant advances.
- Program Offices follow the strategic plan to carry out a specific portfolio of selected facilities & experiments to obtain the science.

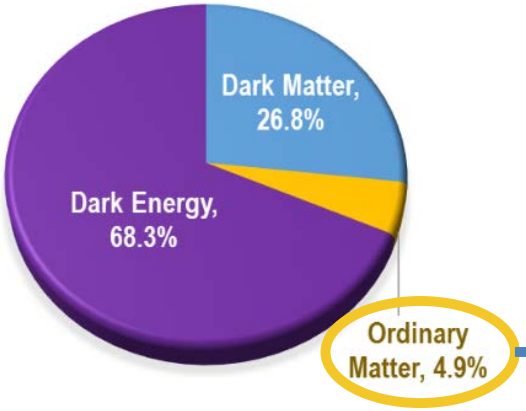
SC is the lead federal agency supporting fundamental scientific research for energy and the Nation's largest supporter of basic research in the physical sciences.

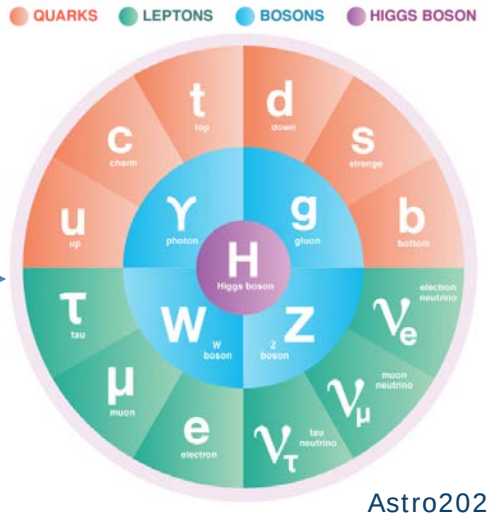
Office of High Energy Physics (HEP) Program Mission

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

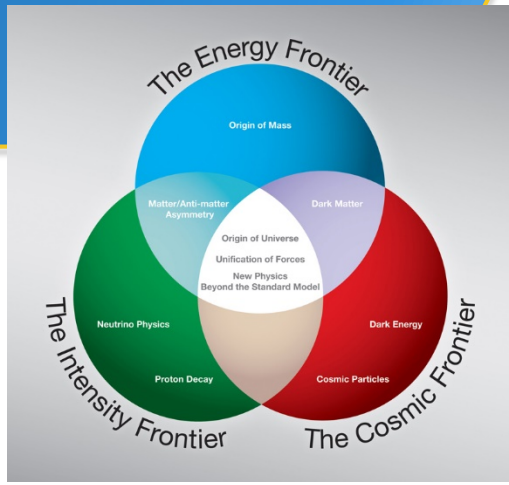
- Discover the elementary constituents of matter and energy
- Probe the interactions between them
- Explore the basic nature of space and time

- 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



<u>HEP is carried out along 3 Frontiers</u>:

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

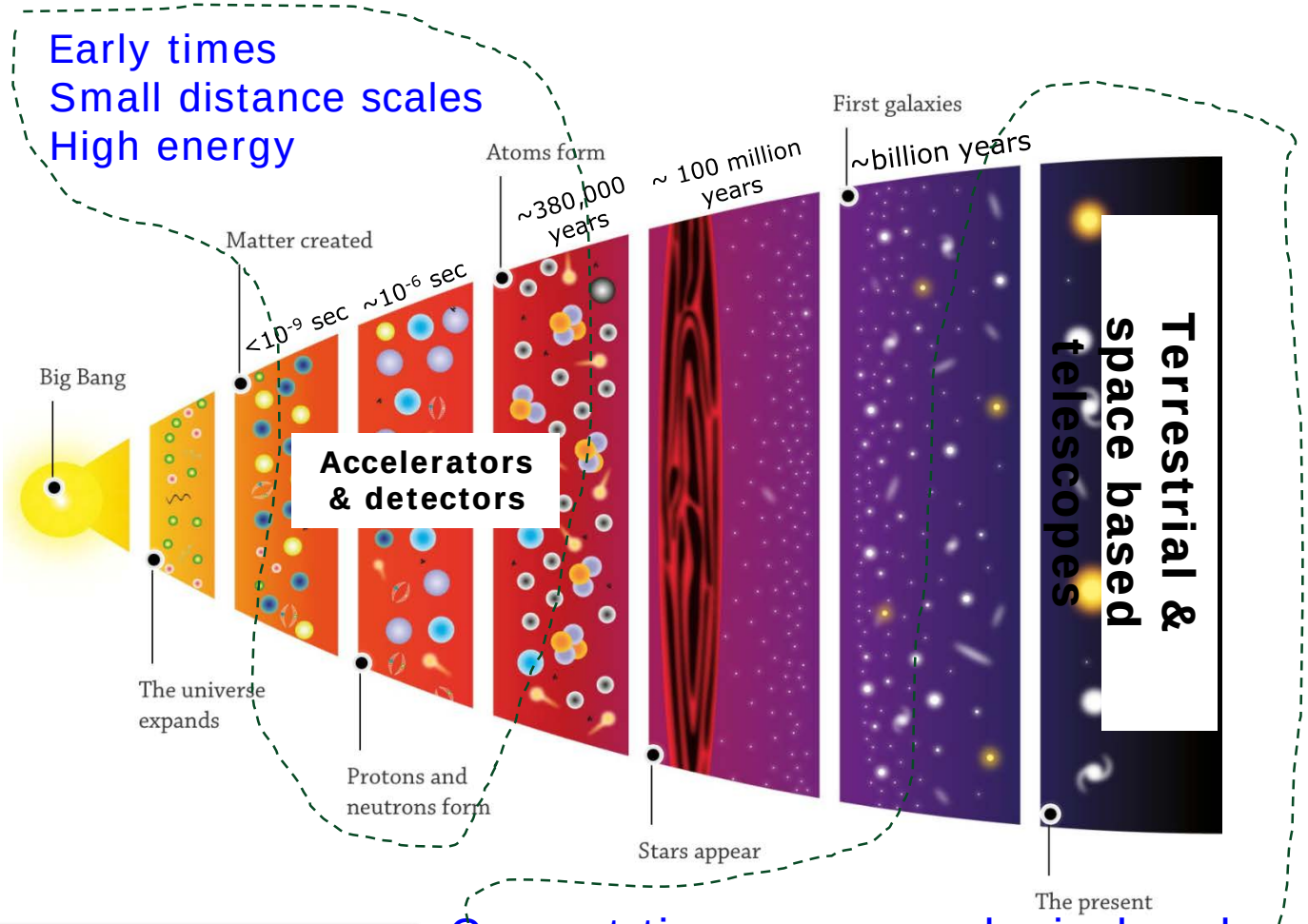
→HEP is primarily a Particle Accelerator based program: **Energy & Intensity Frontiers**

→Cosmic Frontier is an increasingly important area for discovery.

- Experiments use naturally occurring data to provide additional input to the Standard Model picture: <u>Cosmic Acceleration</u> (Dark Energy, Inflation), search for <u>Dark Matter</u> particles, <u>New Physics</u> (neutrino properties, relic particles, etc)

From Quarks to the Cosmos

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



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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
  - Subpanels - CMB-S4 Concept Design Team (CDT), Gemini-Blanco-SOAR Telescopes roles

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).
- 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

Program Execution, Priorities

DOE is a mission-oriented agency→
The **projects** are selected by the (P5) community-based 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**

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

- Especially for the Cosmic Frontier, the **2009 HEPAP/PASAG report criteria** guides determination of where, and at what level HEP participates in specific projects
  - In particular, we consider where HEP community brings unique or leadership contributions

Cosmic Frontier – Partnerships & Funding Models

Particle Physics is Global

- Form partnerships or use other agency's/country's facilities when needed
- Most HEP projects have interagency or international partners or contributions
- **Use our own processes to decide on projects, then coordinate planning, funding, and execution via Joint Oversight Groups, reviews, resource boards, regular meetings, MOU's**

Interagency: NSF & NASA partnerships on most experiments and projects

NSF-PHY: primarily ground-based gamma-ray, dark matter
NSF-AST: primarily dark energy
NSF-AST, -PHY, -Polar: CMB
NASA: space-based gamma-ray, cosmic ray

International: partners or contributions on most experiments and projects

- Across HEP, we have agreements to participate in science with major funding agencies (e.g. Italy, France, CERN, etc) and with details on specific projects
- Some projects develop the international partnerships themselves and report it to us (e.g. France on LSSTCamera, DESI)

Public/Private:

- No specific partnerships with agreements that HEP manages at this time
- There are many private contributions to R&D and projects in our program; LSST, DESI, dark matter detector and other detector development

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HEP Budget

HEP Budget: FY18-20

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 Budget continues support for P5-guided investments in mid- & long-term

FY 2020 Request: balanced program of world-leading research, facilities and projects

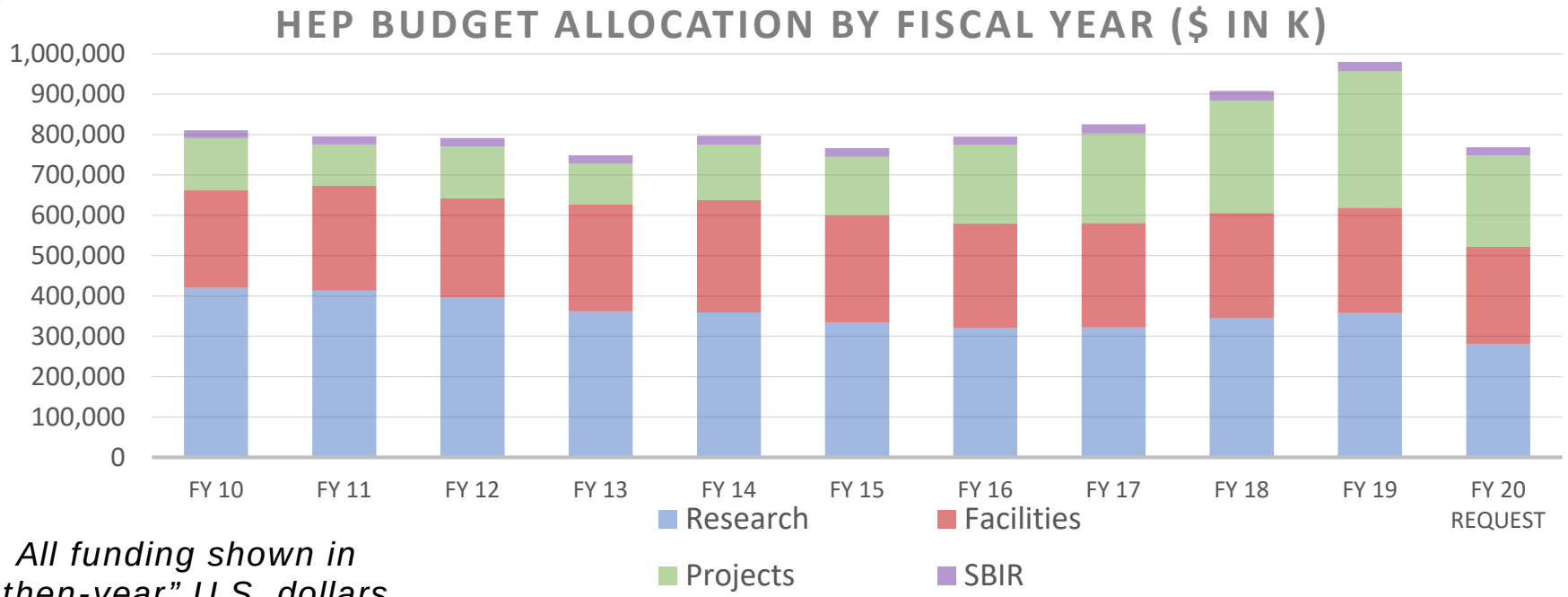
- Quantum Information Science: SC-wide initiative to accelerate discovery
- Artificial Intelligence (AI)-Machine Learning (ML) research to tackle challenges across HEP
- Cosmic Microwave Background Stage 4 (CMB-S4) R&D to develop large-scale project

FY 2020 House Marks

- DOE Office of Science: **$6.87B,** $285M above FY19 enacted and $1.32B above FY20 request
- High Energy Physics: **$1.045B**
  - [*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 DOE 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 Budget: Overall Trends

- P5 strategy continues to define investments for the future



All funding shown in "then-year" U.S. dollars

- **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

Budget Process, Planning

HEP funds are developed in an iterative process through DOE, OMB, Congress etc. Priorities are balanced across activity type (Research, Operations, Projects), Frontier (Cosmic, Energy, Intensity, Theory…), etc.

Project budgets – developed by project team and extensively reviewed. Once its approved and baselined, the funds are planned and fixed.

Experimental Operations budgets – developed by operations team and extensively reviewed. HEP works to provide necessary funds according to the plan. Since Cosmic Frontier operations needs are rapidly increasing, the request is about 25% more than we can fund in the last few years; we are working to plan the full support needed as we go forward.

Lab Research– developed by lab program and reviewed by HEP, with extensive comparative peer reviews every 3-4 years within the lab program and with other labs Cosmic Frontier efforts. HEP works to provide necessary funds to support the lab, within priorities, etc. Over the last few years, typically the lab needs are ~ 10% more than funding.

University Research (grants) – developed by program managers to carry out needs and also based on "pressure" from the community in terms of funds requested. Typical grants are for 3 years and then undergo comparative review for renewals. Since scientists are supported to carry out design, fabrication & operations as well as data planning and analysis, typically they are renewed if they're carrying out critical roles well & align with priorities in the program. Over the last few years, typically the total requests are about 2 times the funding.

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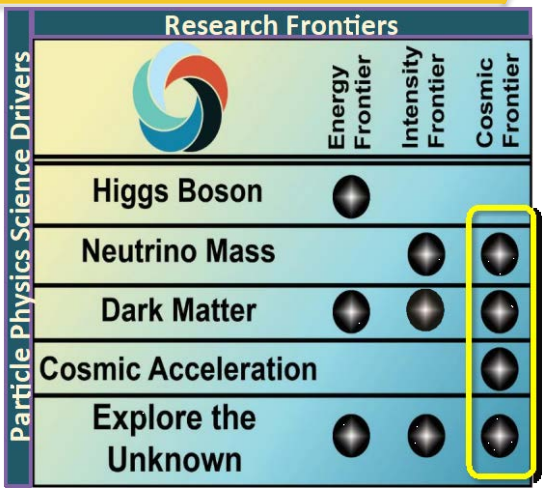
Cosmic Frontier – Program, Budget

Cosmic Frontier Experimental Research Program

Address P5 science drivers using naturally occurring cosmic phenomena via deep underground detectors, ground-based telescopes & arrays, space missions.
→ Specific set of Projects are carried out to provide significant leaps in science and capabilities, based on P5 strategic plan.



We support the community to carry out these projects/experiments.

- Research funding supports scientists at labs & universities to participate in ALL experimental phases →design, fabrication, operations, data planning & analysis.
- Research funding priority is to support scientific efforts directly in line with HEP program & project priorities, responsibilities & science goals.
- The HEP model is for a science collaboration to carry out experiment in all phases to deliver the best science. Review panels consider this model in their assessments.

Program Planning: follow P5 Strategic Plan

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

Cosmic Frontier Program

Study **cosmic acceleration (dark energy)** through staged program of complementary surveys (in partnership with NSF-AST)

- Imaging surveys map cosmic structure over vast volumes of space: *Dark Energy Survey (DES)* completed operations, *Large Synoptic Survey Telescope (LSST)* camera in fabrication
- Spectroscopic surveys build deep, 3D maps of cosmic structure and growth: *eBOSS* completed, *Dark Energy Spectroscopic Instrument (DESI)* in fab

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

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

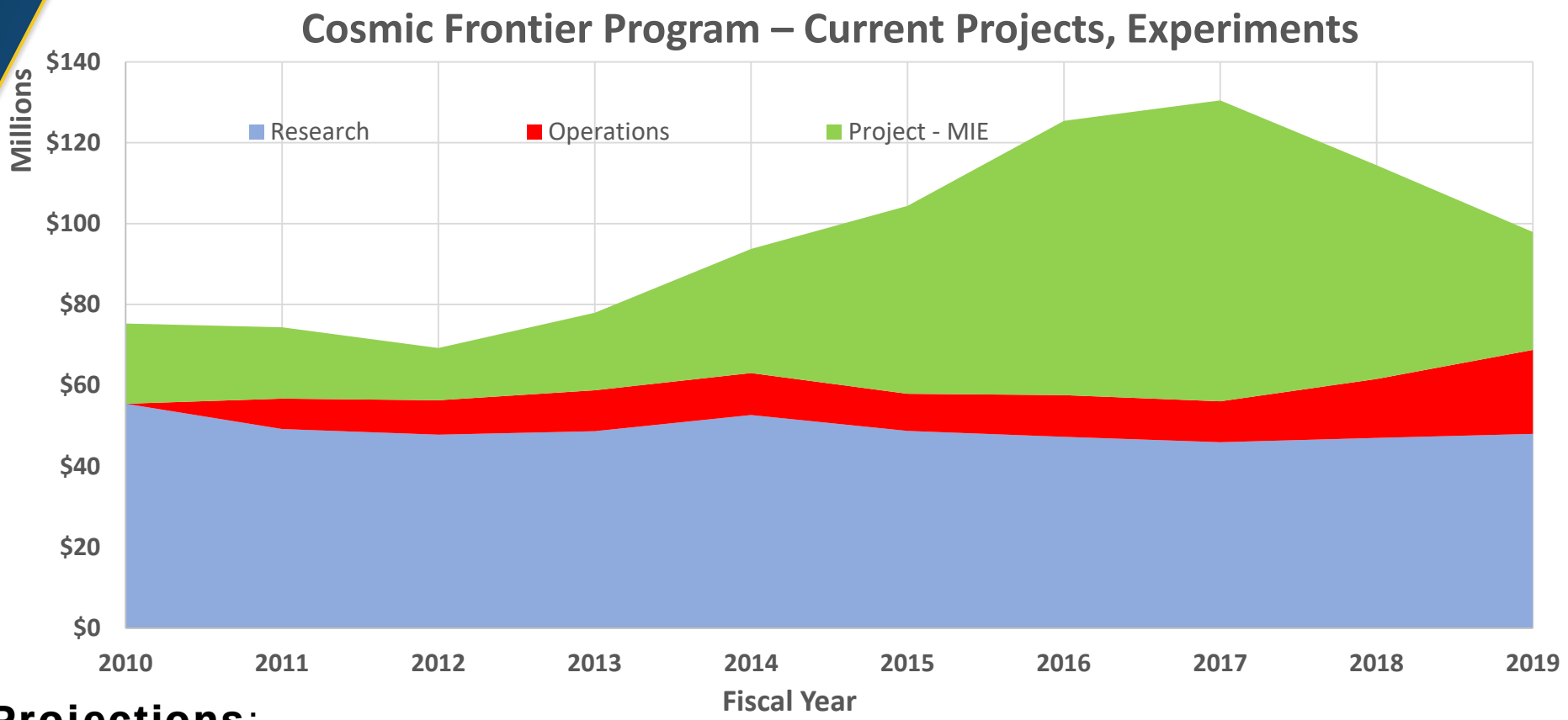
Search for **dark matter** through direct detection experiments over a wide mass range (in partnership with NSF-PHY); Investigate new directions with small project concepts

- High- and low-mass WIMP sensitivity: *LZ* and *SuperCDMS-SNOLAB*, in fab
- Axion (ultralow mass) experiment: *ADMX-G2* in operation

Explore the unknown, e.g. through high energy particles from **dark matter** annihilations in cores of galaxies (in partnership with NSF, NASA)

- Cosmic- and gamma-ray detectors on Earth and in space: *HAWC*, *Fermi/GLAST*, *AMS* in operation

Cosmic Frontier Budget History (FY10-19)



Projections:

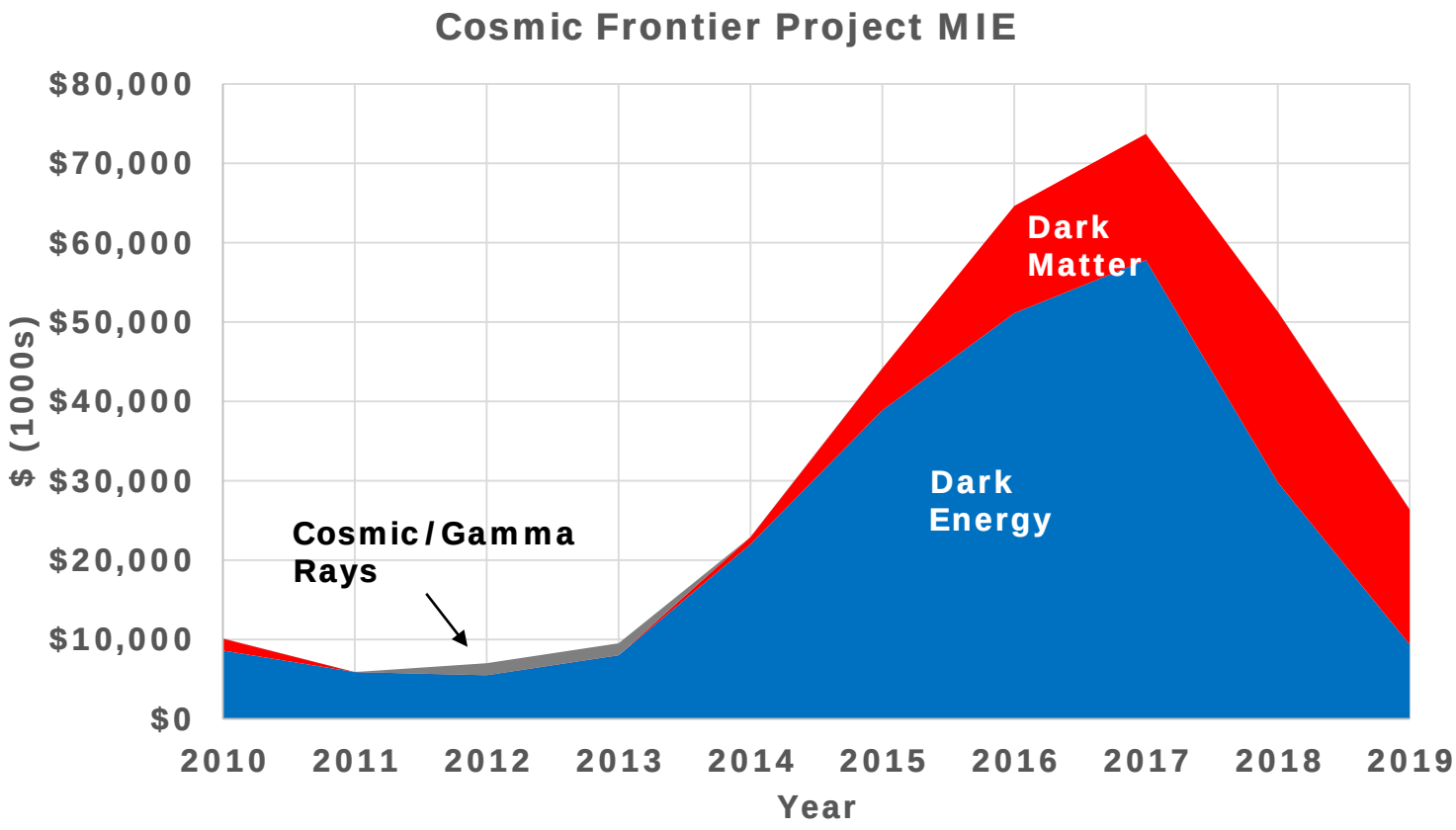
- As the current Projects complete, estimated needs for Experimental Operations ramps up to ~ $55M to $60M by FY2024; levels to ~ $40M by FY2030.
- Future opportunities: Compelling Cosmic Frontier Projects will be considered and supported within available overall HEP Project funds. Guidance from Astro2020,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

Cosmic Frontier Budget Distributions

Budget – Fractions by Activity Type

	FY2015	FY2016	FY2017	FY2018	FY2019
TOTAL (in $K)	**104,367**	**125,381**	**130,420**	**114,413**	**97,895**
Research fraction	0.47	0.38	0.35	0.41	0.49
Operations fraction	0.09	0.08	0.08	0.13	0.21
Project fraction	0.44	0.54	0.57	0.46	0.30

Cosmic Frontier – Project Budget by Activity



Cosmic Frontier – Activities by Year

Year	Funded Activity	Dark Matter	Dark Energy	Cosmic, Gamma	CMB
FY15	Operating	SuperCDMS-Soudan, COUPP, DMTPC, DarkSide-50, LUX ADMX-G2, LZ, SuperCDMS-SNOLAB	DES, eBOSS	AMS, Auger, FGST-LAT, HAWC, VERITAS	SPTpol
FY15	Design, Fabrication		DESI, LSST		SPT-3G
FY16	Operating	SuperCDMS-Soudan, COUPP, DMTPC, DarkSide-50, LUX ADMX-G2, LZ, SuperCDMS-SNOLAB	DES, eBOSS	AMS, Auger, FGST-LAT, HAWC, VERITAS	SPTpol
FY16	Design, Fabrication		DESI, LSST		SPT-3G
FY17	Operating	ADMX-G2, LUX	DES, eBOSS	AMS, Auger, FGST-LAT, HAWC	SPT-3G
FY17	Design, Fabrication	LZ, SuperCDMS-SNOLAB	DESI, LSST		
FY18	Operating	ADMX-G2	DES, eBOSS	AMS, FGST-LAT, HAWC	SPT-3G
FY18	Design, Fabrication	LZ, SuperCDMS-SNOLAB	DESI, LSST		
FY19	Operating	ADMX-G2	DES, eBOSS	AMS, FGST-LAT, HAWC	SPT-3G
FY19	Design, Fabrication	LZ, SuperCDMS-SNOLAB	DESI, LSST		CMB-S4
FY20	Operating	ADMX-G2, LZ	DESI	AMS, FGST-LAT, HAWC	SPT-3G
FY20	Design, Fabrication	LZ, SuperCDMS-SNOLAB	DESI, LSST		CMB-S4

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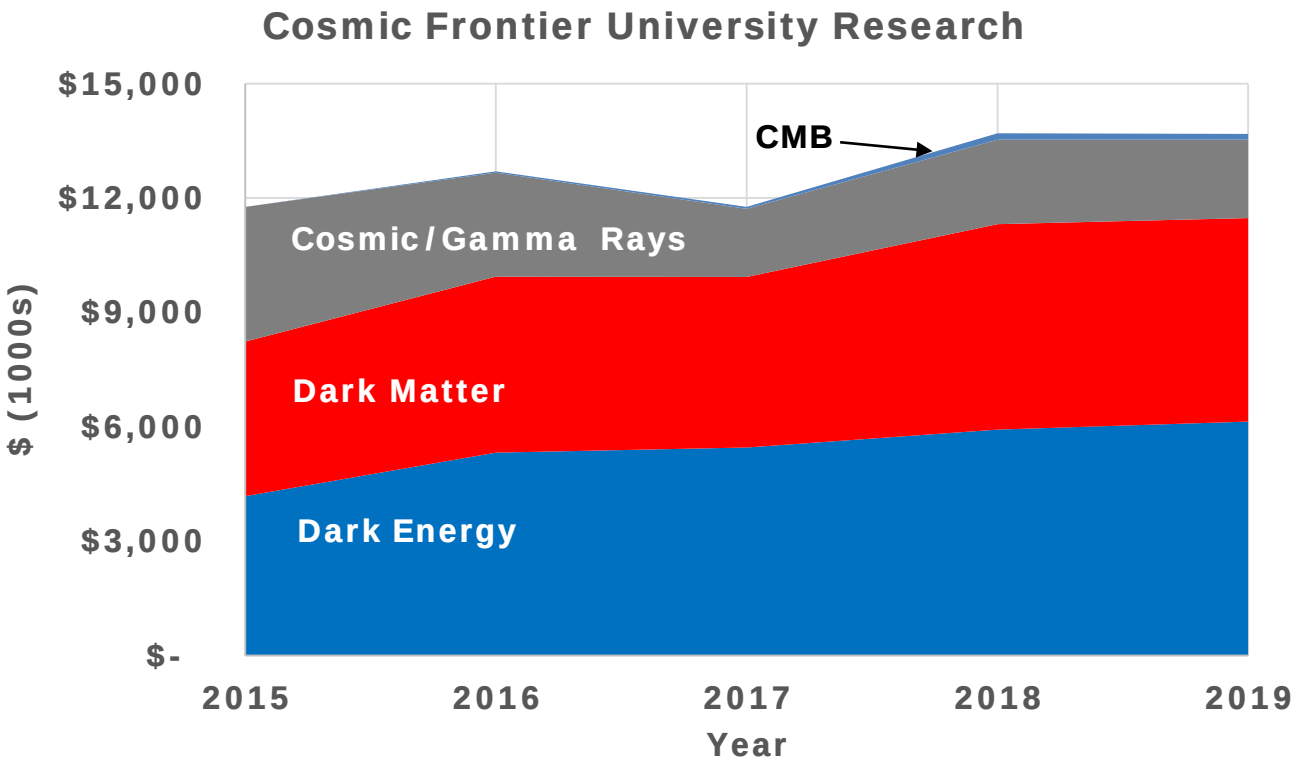
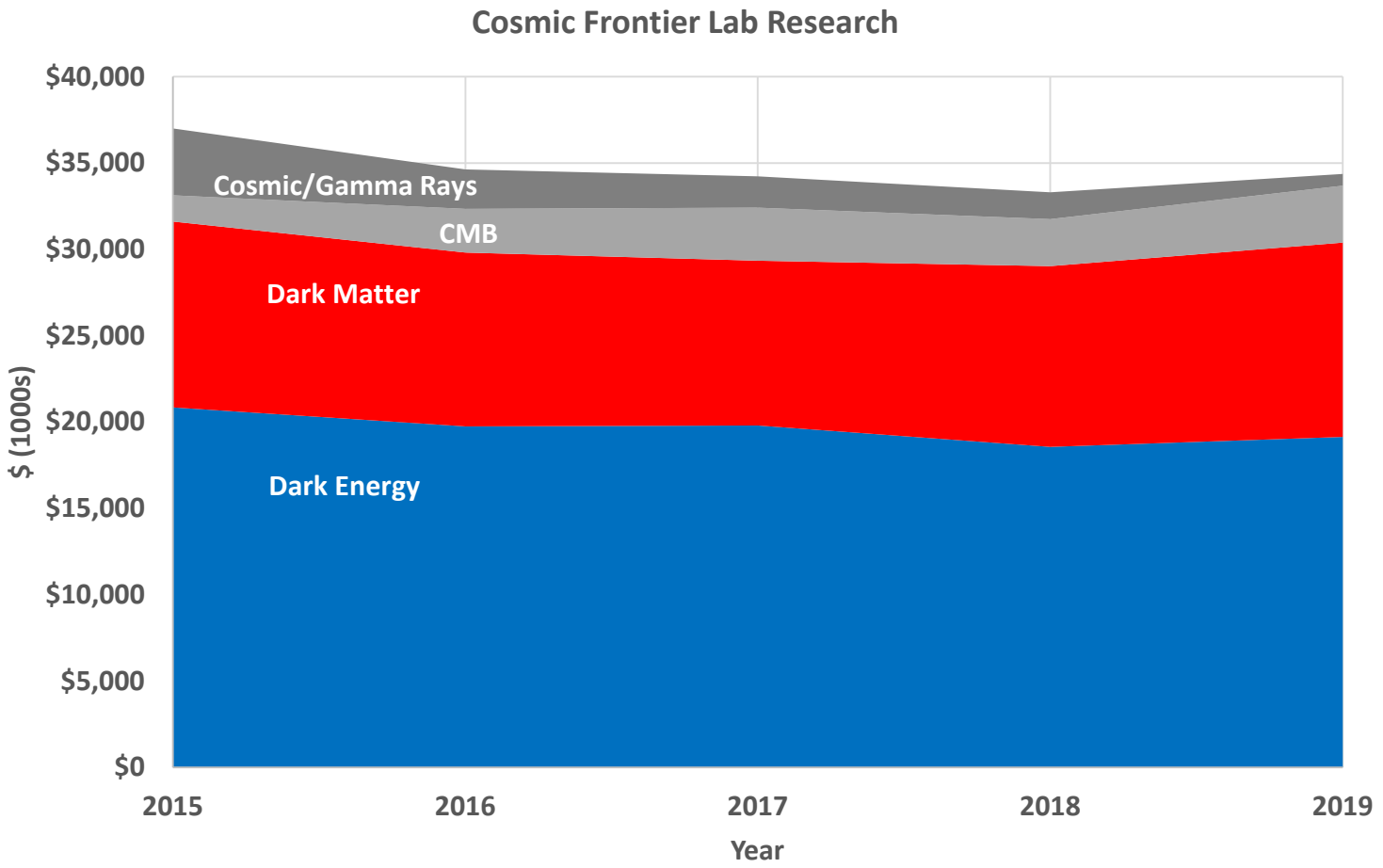
Cosmic Frontier Research Funding: Budgets, Opportunities, Statistics

Cosmic Frontier – University Research Budget by Activity



Cosmic Frontier – Lab Research Budget by Activity



Cosmic Frontier Budget Distributions; Funding Opportunities & Reviews

Budget – Research Fractions for Lab vs. University Grants

	FY15	FY16	FY17	FY18	FY19
TOTAL Lab + Univ ($K)	48,774	47,322	45,990	47,008	48,051
Univ fraction	0.24	0.27	0.26	0.29	0.28
Lab fraction	0.76	0.73	0.74	0.71	0.72

Funding Opportunities & Reviews

- Call for proposal & reviews annually for University grants
- Panel reviews of Lab research programs ~ every 3-4 years

Funding Opportunities in HEP, Cosmic Frontier

*** Primary HEP University Researcher support**

➔HEP

***Research Opportunities in High Energy Physics ("Comparative Review")**

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

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

- **Research Opportunities in Accelerator Stewardship**

Supports basic accelerator research of broad benefit; conducted with 11 federal agencies

- **DOE Traineeship in Accelerator Science & Engineering:** Student support

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/

- **Quantum Information Science Enabled Discovery**
- **SC "General" [always open] -** HEP uses this primarily for conferences and unforeseen circumstances (e.g. equipment failure)
- **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

Cosmic Frontier Research: University Grant Statistics

		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%

FFF = fully forward funding; for grants < $1million, we have to provide all funds in the first year.

Cosmic Frontier Research - Early Career Award Statistics

SC-wide Early Career program: Each Office (e.g. HEP) runs its own review panels; HEP considers proposals and reviews across the program

Cosmic Frontier statistics:

	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**

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Related Efforts; Data & Computing

HEP Efforts related to the 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 & Accelerator R&D programs:

- State-of-the-Art Detector technology development
  - Active R&D developing next generation detectors, including CCDs, TES superconducting bolometers, MKIDs, readout electronics, optics. Key elements for DES, LSST, CMB-S4.
  - Accelerator & Detector R&D: 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
  - NERSC facility allocations for HEP Cosmic Frontier Simulations and Experiments
- High Performance Computing → Exascale; Comp HEP & ASCR coordination & partnerships on some efforts, including Cosmic Simulation and Data analytics
- **Artificial Intelligence / Machine-learning** becoming an agency area of particular interest

Quantum Information Science (QIS) – quickly growing area

- 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)

HEP supports several cross cut computing initiatives in partnership and/or coordination with the Advanced Scientific and Computing Research (ASCR) program at Office of Science, DOE. These include SciDAC https://www.scidac.gov/ partnerships/high-energy-physics.html and the HEP Center for Computational Excellence (CCE) https://press3.mcs.anl.gov/hepfce/.

The Exa Scale Project (ECP) at DOE funds development of selected scientific codes and software that are expected to be early users of Exa Scale Computers. Selected topics include Cosmological Simulations, Plasma accelerators and lattice QCD.

DOE Leadership Class Computing Facilities at ANL, ORNL, and NERSC at LBNL are available for science.

There are new AI and ML efforts that include data science. There is interest at Office of Science level for inter-agency coordination for data science and for making available scientific data sets for AI and data science use.

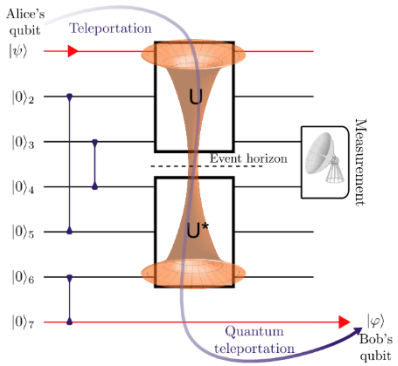
Quantum Information Science Enabled Discovery (QuantISED) for High Energy Physics

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



Office of Science Data Management Plan

- **Focus of the SC Digital Data Management is the sharing and preservation of digital research data**
  - Data management involves all stages of the digital data life cycle including capture, analysis, sharing, and preservation
  - See Dr. Laura Biven's presentation on SC Digital Data Management, Sept. 2014 HEPAP meeting: http://science.osti.gov/hep/hepap/meetings/201409/
  - FOAs issued by HEP require Data Management Plan (DMP) compliance with the SC Statement
    - SC statement on DMPs: https://science.osti.gov/Funding-Opportunities/Digital-Data-Management
- Most experiments have developed DMPs for their collaborations
  - When applying for financial assistance (universities) or submitting FWPs (labs), PIs can cite the DMPs for their experiments with the appropriate links

Office of Science Data Management Plan - Details

SC statement: https://science.osti.gov/Funding-Opportunities/Digital-Data-Management

All proposals submitted to the Office of Science for research funding must include a Data Management Plan (DMP) that addresses the following requirements:

1.DMPs should describe whether and how data generated in the course of the proposed research will be shared and preserved. If the plan is not to share and/or preserve certain data, then the plan must explain the basis of the decision (for example, cost/benefit considerations, other parameters of feasibility, scientific appropriateness, or limitations discussed in #4). At a minimum, DMPs must describe how data sharing and preservation will enable validation of results, or how results could be validated if data are not shared or preserved.

2.DMPs should provide a plan for making all research data displayed in publications resulting from the proposed research open, machine-readable, and digitally accessible to the public at the time of publication. This includes data that are displayed in charts, figures, images, etc. In addition, the underlying digital research data used to generate the displayed data should be made as accessible as possible to the public in accordance with the principles stated above. This requirement could be met by including the data as supplementary information to the published article, or through other means. The published article should indicate how these data can be accessed.

3.DMPs should consult and reference available information about data management resources to be used in the course of the proposed research. In particular, DMPs that explicitly or implicitly commit data management resources at a facility beyond what is conventionally made available to approved users should be accompanied by written approval from that facility. In determining the resources available for data management at Office of Science User Facilities, researchers should consult the published description of data management resources and practices at that facility and reference it in the DMP. Information about other Office of Science facilities can be found in the additional guidance from the sponsoring program.

4.DMPs must protect confidentiality, personal privacy, Personally Identifiable Information, and U.S. national, homeland, and economic security; recognize proprietary interests, business confidential information, and intellectual property rights; avoid significant negative impact on innovation, and U.S. competitiveness; and otherwise be consistent with all applicable laws, regulations, and DOE orders and policies. There is no requirement to share proprietary data.

HEP Computing Challenges

- P5 recommended a program of challenging scientific experiments that have equally challenging computing needs
  - As an example, in FY2019, 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

Data Sets – some are hosted in different places

Legacy Survey data http://legacysurvey.org
This serves as imaging data for DESI, and a fair fraction of it was obtained with DECam.

DeepSky data https://c3.lbl.gov/nugent/deepsky.html
- Palomar-QUEST and SNfactory data, both of which were DOE funded

NERSC CDR has all BOSS and eBOSS public data and will have final eBOSS data

NERSC hosts Planck data and selected data from other CMB experiments on the community project space.

DES raw data underwent independent low level processing at NOAO and then high level processing at NERSC with an independent object identification pipeline. The latter are on the Legacy Survey website.

DES has DR1 https://www.darkenergysurvey.org/the-des-project/data-access/

BOSS is completely public with SDSS DR12 https://www.sdss.org/dr12/

eBOSS currently has SDSS DR15 https://www.sdss.org/dr15/ and early in 2020 will have the final data release

Fermi/LAT data is hosted at GSFC

HAWC public data are centralized on the data.hawc-observatory.org website

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Summary

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!

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The National Academies' Astro2020 Panel on An Enabling Foundation for Research, chaired by David Spergel of the Flatiron Institute,

Interest is in:
Overall DOE funding in various areas of astronomy and astrophysics research (including software development) in past 5 years--including total requested vs. awarded

Balance of funding of facilities vs. individual PIs

Future of archives

Interaction with data science and supercomputing efforts within the agency

Funding models including inter-agency, international, and public-private