U.S. DEPARTMENT OF ENERGY | Office of Science

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

Committee on Astronomy & Astrophysics (CAA)

March 24, 2021

Kathy Turner, Cosmic Frontier Program Manager

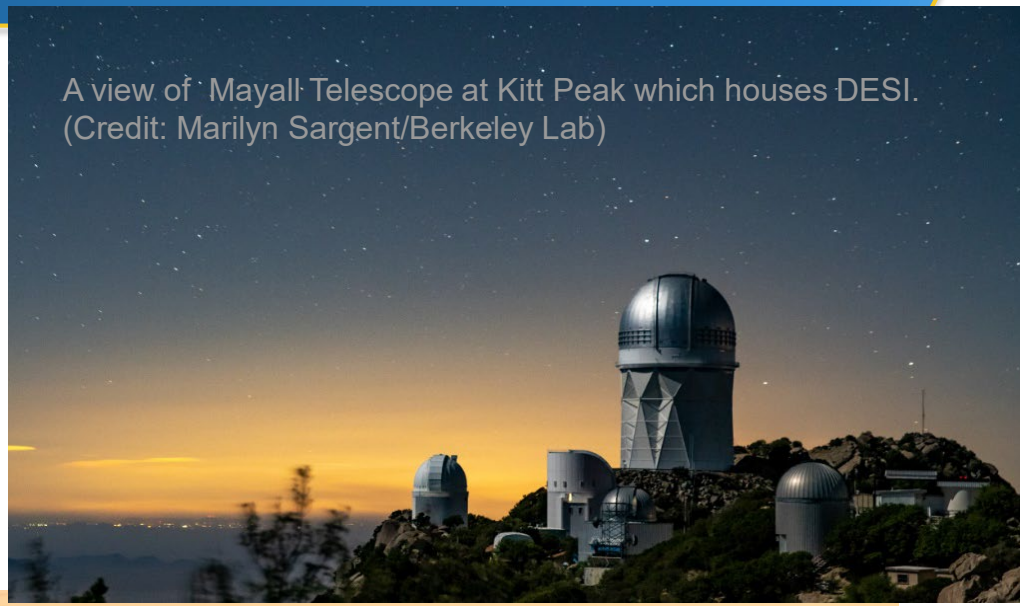
Cosmic Frontier group members:

- *Current: Karen Byrum (Detailee), Drew Baden (IPA)*
- *Term recently ended: Eric Linder (IPA)*

Jim Siegrist, Associate Director for High Energy Physics

OUTLINE

- **DOE, HEP & Cosmic Frontier intro**
- **News: DESI**
- **Status: Vera C. Rubin Observatory**
- **CMB-S4**
- **Dark Matter**
- **DOE/NASA RFI**
- **COVID**
- Other experiments & projects
- **Budget**
- **International**
- **Research, Grant statistics**



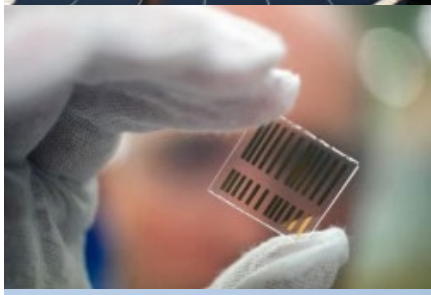
A view of Mayall Telescope at Kitt Peak which houses DESI. (Credit: Marilyn Sargent/Berkeley Lab)

Mission of the US Department of Energy (DOE)

The mission of DOE 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 DOE stakeholders to maximize mission success.

➔DOE grew out of the Manhattan Project effort to develop the atomic bomb during World War II, and various energy-related programs that were dispersed throughout various Federal agencies.



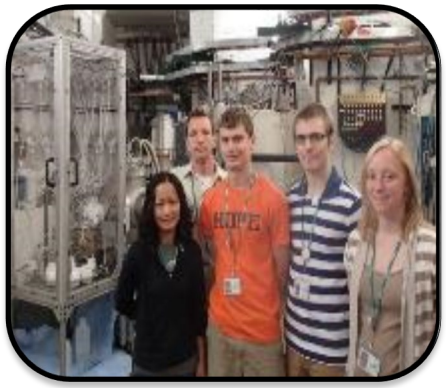
Mission of the DOE Office of Science (SC)

- A research funding agency and a steward of national research infrastructure.

The mission is to deliver scientific discoveries and major scientific tools to transform our understanding of nature and advance the energy, economic, and national security of the US.

Largest Supporter of Physical Sciences in the U.S.

Funding at >300 Institutions, including 17 DOE Labs



Over 23,000 Researchers Supported

Over 33,000 Users of 28 SC Scientific Facilities

SC is the nation's largest federal sponsor of basic research in the physical sciences and is a major supporter of research in such key scientific fields as physics, materials science, and chemistry.

SC is also the lead federal agency supporting fundamental scientific research related to energy. Six offices: Advanced Scientific Computing, Basic Energy Sciences, Biological Energy Research, Fusion Energy, **High Energy Physics**, Nuclear Physics

DOE/SC Policies, Procedures → Diversity, Equity, Inclusion

The DOE Office of Science (SC) is fully committed to fostering safe, diverse, equitable, and inclusive work, research, and funding environments that value mutual respect and personal integrity.

As President Obama said in 2011, "*We are at our best when we draw on the talents of all parts of our society" (Executive order 13583).*

➔In recent years, it has become obvious how far we still have to go.

DOE has long had policies in place prohibiting discrimination and harassment by institutions that we fund (at academic institutions, small businesses, and DOE national labs), and by employees. **A new www site is in place to consolidates DOE's policies and procedures:**

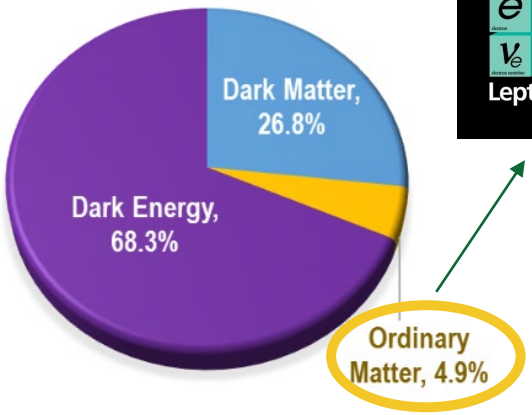
- https://science.osti.gov/sc-2/Research-and-Conduct-Policies/Diversity-Equity-and-Inclusion

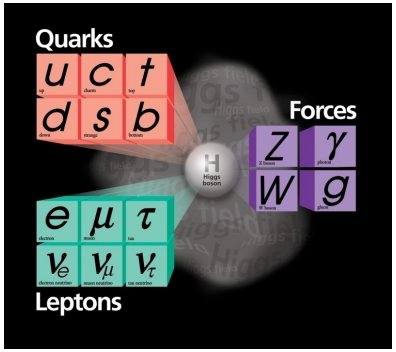
- SC's effective stewardship and promotion of diverse and inclusive workplaces that value and celebrate a diversity of people, ideas, cultures, and educational backgrounds is foundational to delivering on our mission.
- Discrimination and harassment undermine SC's ability to achieve its mission by reducing productivity, discouraging or inhibiting talent retention and career advancement, and weakening the integrity of the SC enterprise overall.

Office of High Energy Physics (HEP) Program Mission

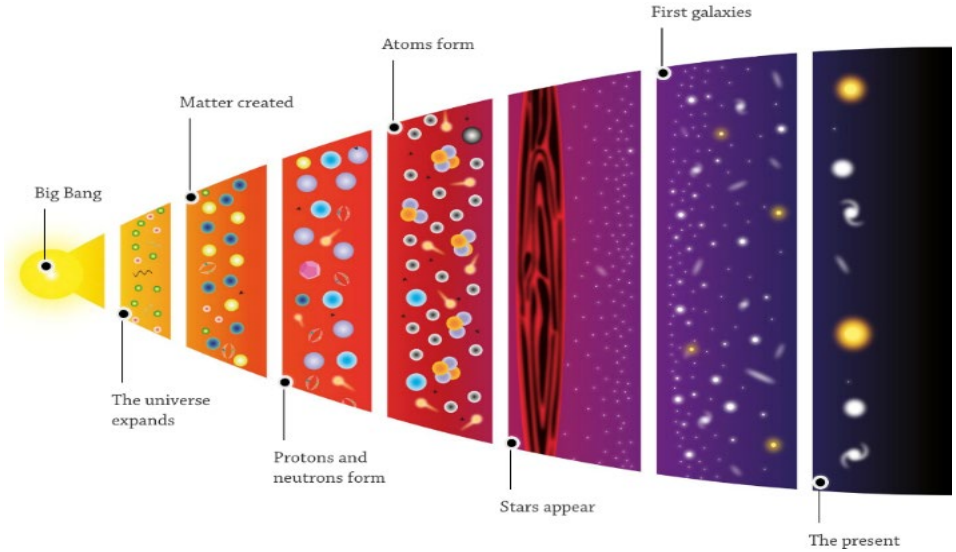
… is to understand how the universe works at its most fundamental level:

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

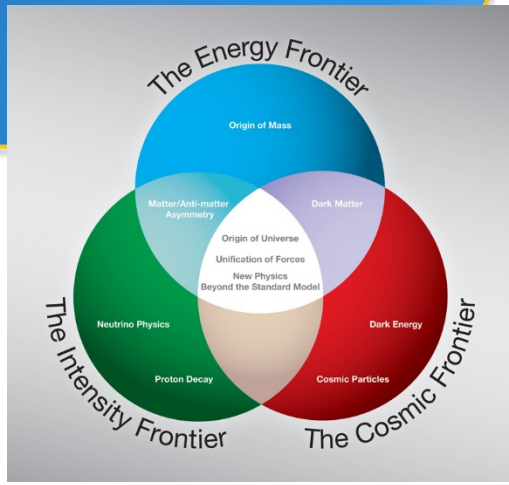




➔Scientific Areas are intertwined: High Energy/Particle Physics, Cosmology, Astrophysics, and Astronomy.



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**

→ The **Cosmic Frontier subprogram**, using naturally occurring phenomena to study Cosmology and Astrophysics, is an **increasingly important area for discovery.**

Crosscutting programs:
- In HEP: Theoretical research, High Performance Computing & Computational HEP, Advanced Detector R&D, Quantum Information Science (QIS), AI/ML
- In SC: Access to supercomputing resources (e.g. NERSC).

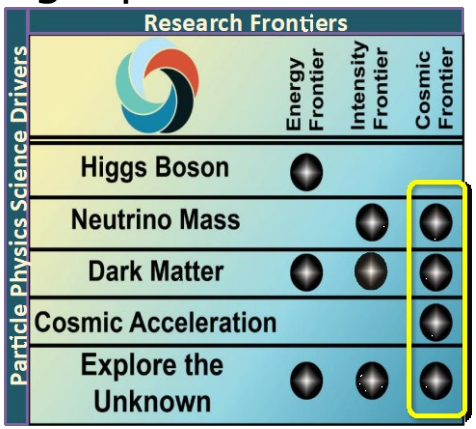
Partnerships: Most projects have interagency (NASA, NSF) and/or international partnerships or contributions.

HEP Guidance & P5 Strategic Plan

HEP gets guidance from 2 federal advisory panels, **HEPAP** & AAAC, as well as the National Academies, and community science studies.

HEP's science and program priorities come from community via HEPAP's Particle Physics Project Prioritization Panel ("P5") strategic plan.

- Provided the critical scientific questions and drivers →
- 10 year plan, with a 20 year vision
- Recommended a portfolio of facilities, projects and experiments that will provide significant leaps in science & capabilities, aligned with the science drivers. The portfolio optimally addresses the science within budget realistic constraints; Also investments in Theory, Detector R&D, Accelerator R&D, etc.

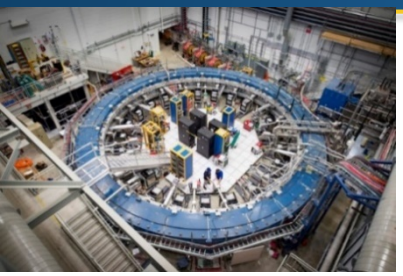


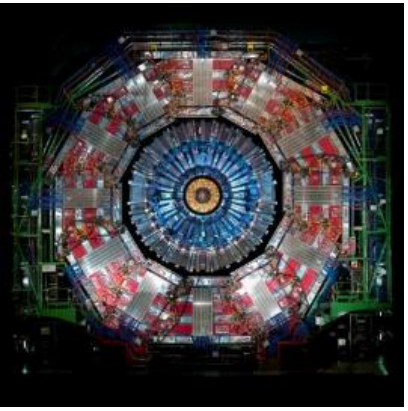
→HEP Community support of the P5 process is a critical part of its success.

Cosmic Frontier recommendations:

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

HEP – Carrying out the Mission





➔ The Mission is carried out by building **projects**, operating **facilities** and **experiments**, and supporting **research** to enable and produce the discovery science

Experimental Science, Technology R&D

- Develop and support a **specific portfolio of projects** based on **community-developed strategic plan (P5)**
- Make **significant, coherent contributions to the selected facilities & projects**, including project management efforts.
- Supports **R&D that will advance the state-of-the-art in particle accelerators and detectors, and to enable new & transformative capabilities in QIS, AI/MI**, & crosscutting technologies
- Support scientific research to carry out our roles, responsibilities and science goals.

Theoretical research support provides the vision and the mathematical framework for understanding and extending our knowledge of fundamental matter, energy, space and time.

HEP supports ~85% of the U.S. particle physics (in $), including **~all our national labs.**

HEP by the Numbers

HEP RESEARCH SPANS

MORE THAN **160** ACADEMIC, NONPROFIT, AND INDUSTRIAL INSTITUTIONS

12 DOE NATIONAL LABORATORIES | **42** STATES AND WASHINGTON, D.C.

13 CORE RESEARCH THRUSTS

OVER **400** ANNUAL HEP PUBLICATIONS IN PEER-REVIEWED SCIENTIFIC JOURNALS

SUPPORTED RESEARCHERS

1,115 PH.D SCIENTISTS *(325 POST-DOCS)*

595 GRADUATE STUDENTS

HEP BY THE NUMBERS (FY 2020)

HEP's mission is to understand how the universe works at its most fundamental level by discovering the elementary constituents of matter and energy, probing the interactions between them, and exploring the basic nature of space and time.

20 NOBEL PRIZES IN PHYSICS

$390 MILLION RESEARCH BUDGET

$25M SBIR/STTR, $118M UNIVERSITIES, $247M DOE LABS

2,215 USERS AT **3** HEP FACILITIES

FERMILAB ACCELERATOR COMPLEX, SLAC FACET-II, BROOKHAVEN ATF

PRESIDENTIAL EARLY CAREER AWARDS FOR SCIENTISTS AND ENGINEERS (PECASE) **15**

OVER **300** ACTIVE AWARDS

$317 MILLION SCIENTIFIC USER FACILITIES AND EXPERIMENTAL OPERATIONS BUDGET

LHC, SURF, RUBIN/LSST, DESI, LZ, AMS, TEST FACILITIES, ETC.

$338 MILLION LINE-ITEM CONSTRUCTION PROJECT AND MAJOR-ITEM OF EQUIPMENT BUDGET

LBNF/DUNE, PIP-II, HL-LHC-ACCELERATOR, HL-LHC-ATLAS, HL-LHC-CMS, CMB-S4, ACORN

U.S. DEPARTMENT OF
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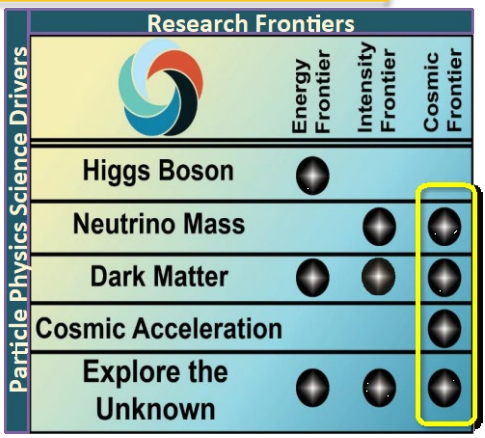
Cosmic Frontier

Cosmic Frontier Experimental Research Program

Address 2014 "P5" strategic plan science drivers using naturally occurring cosmic phenomena via ground-based telescopes & arrays, space missions, and deep underground detectors



Cosmic Acceleration:

- Imaging & Spectroscopic surveys to determine the nature of **Dark Energy**
- Study the Inflationary era using its imprint on the cosmic microwave background (**CMB**) at energies near the Planck scale (with NSF)

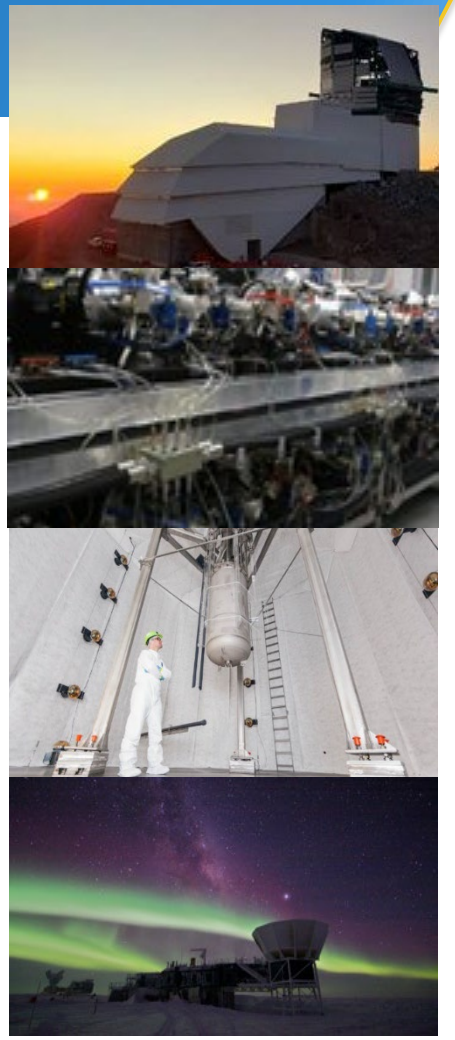
Dark Matter: Primary efforts are direct-detection searches for particle dark matter (WIMPs; axions) through deep underground experiments

- Also indirect searches using cosmic-ray & gamma-ray data

Neutrino Mass: Unique constraints from Dark Energy and CMB experiments

Explore the unknown: always searching for New Physics

Cosmic Frontier Program



Dark Energy

- Dark Energy Survey **(*DES*)** final data processing & analyses are continuing
- Dark Energy Spectroscopic Instrument (***DESI***) in operations phase
- ***Vera C. Rubin Observatory, Camera*** **MIE project** almost complete, now carrying out **Commissioning & Facility Operations** planning; Legacy Survey of Space & Time (LSST) starts ~ 2024; ***DESC*** (Dark Energy Science Collab) carrying out dark energy planning and studies

Cosmic microwave background (CMB)

- South Pole Telescope 3rd Generation (***SPT-3G***) – in operations
- *CMB-stage 4 (**CMB-S4**)* in planning; CD-0 in 2019, Congress approved in FY21, working towards CD-1; Collaboration planning project and science

Dark Matter direct detection

- ***ADMX-G2*** axion search in operations
- ***LZ*** MIE project complete, now commissioning; data-taking summer 2021
- ***SuperCDMS-SNOLAB*** MIE project in fabrication phase; being restructured due to COVID and other issues; data taking 2023
- Dark Matter New Initiatives (DMNI) for new small projects to address the 2019 Basic Research Needs; 4 Cosmic Frontier concepts in design and project execution planning phase (***ADMX 2-4, DM-Radio, OSCURA, TESSERACT)***

Explore the unknown – search for New Physics, e.g. relic particles, high energy acceleration mechanisms

- Operating: **AMS** on the Space Station, **Fermi/LAT** mission; **HAWC** in Mexico

Dark Energy Spectroscopic Instrument (DESI) Experiment

DOE's DESI is taking data!

- Data-taking operations started mid-December 2020
- World's premier multi-object spectrograph and the first **Stage IV dark energy** project to start **operations**

DOE/LBNL-led project: instrumentation, data management system, upgrades of NSF's Kitt Peak Mayall telescope (including MOSAIC camera)

- Commissioning complete & ready to take data in March 2020; had to shut down due to covid-19. Project CD-4 May 2020

Cost ~ $56M

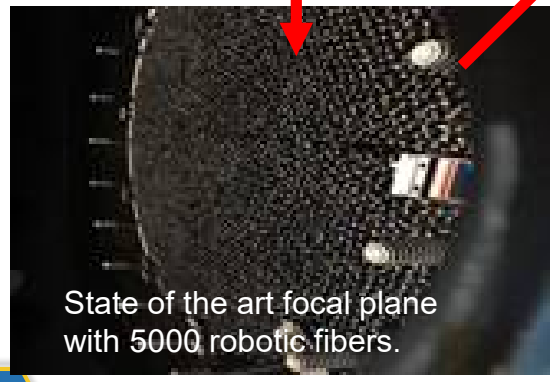
- HEP has MOU w/NSF-AST to "lease" the Mayall telescope; full support started in FY2019

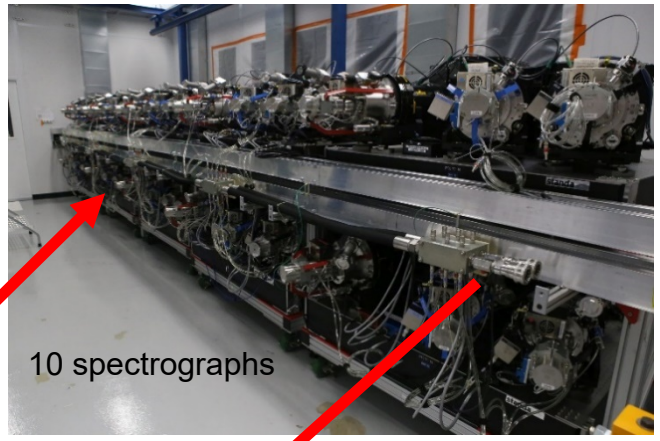
- Designed and built by large international collaboration w/160 grad students.
- Partners: STFC, Heising-Simons, Gordon & Betty Moore, France, Mexico, Spain, NSF
  - **Thank you for strong support by NSF, NOIRLab and KPNO**

DESI Instrumentation

DESI's state of the art instrumentation covers an 8 square degree field of view, about 38 times larger than that of the full moon, including:

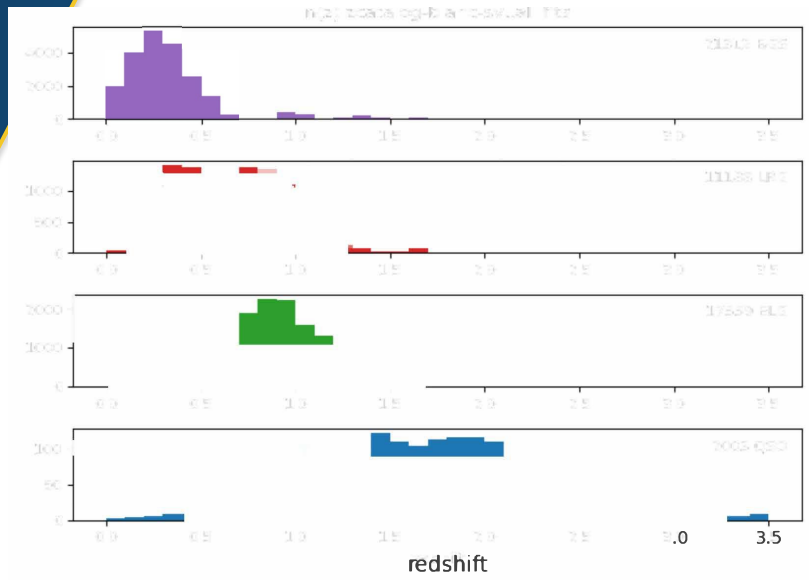
- 6 exquisitely polished corrector lenses
- 5000 fiber-fed robotic positioners – focal plane
- 10 spectrographs, each with 3 wavelength ranges of blue (360 to 555 nanometers), red (555 to 656 nm) and infrared (656 to 980 nm)





To data processing at NERSC supercomputing center.

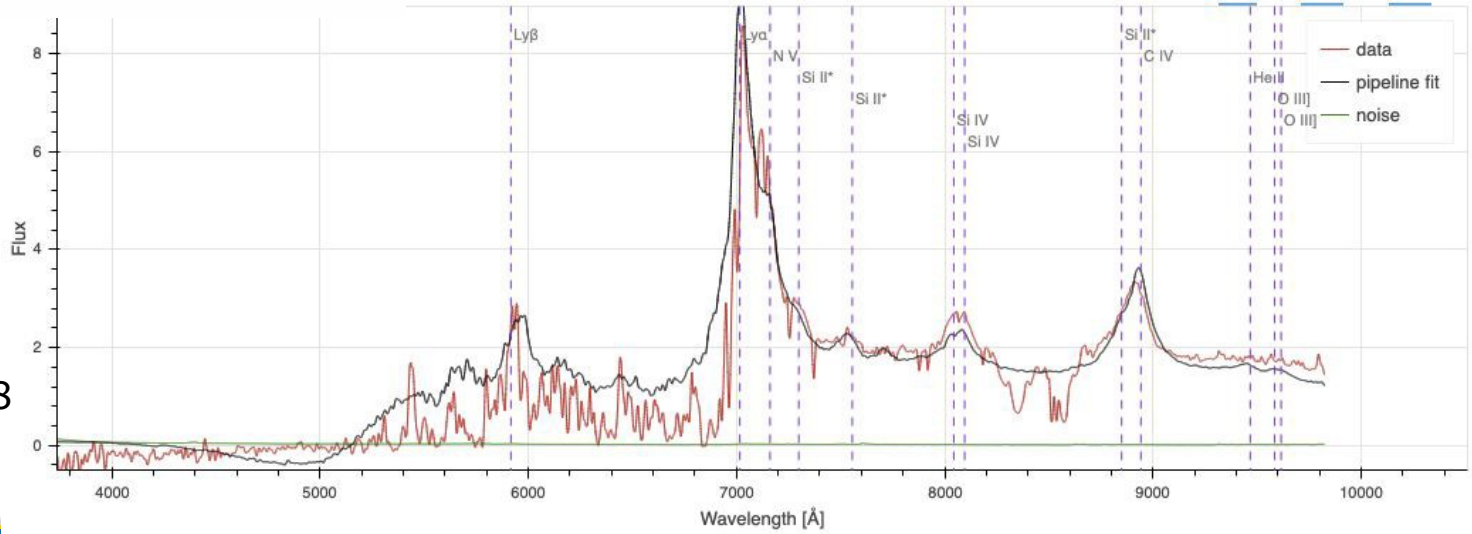
Dark Energy Spectroscopic Instrument (DESI) – Taking Data!



Redshift Distributions of the 4 principal target classes (Dec.2020 data only)

LBNL continues to lead Operations Phase & Scientific Collaboration

- Now in Survey Validation (SV) phase, followed by the 5 year science survey starting ~ May 2021.
- Covid-19 era observing now includes only one on-site lead observing scientist, with remote observing & data quality scientists.

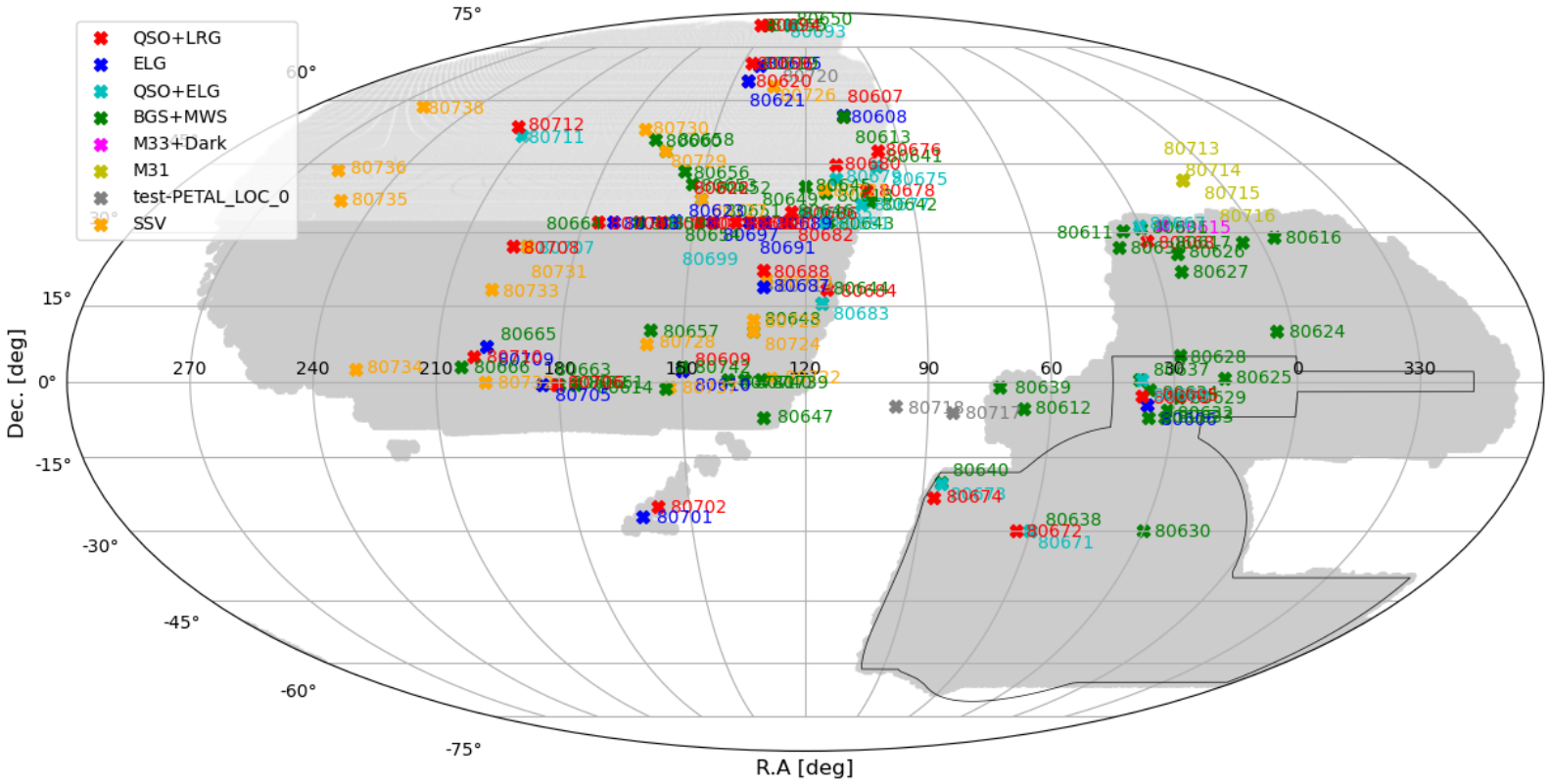


High quality spectrum of a z=4.8 quasar observed in Dec.2020

Dark Energy Spectroscopic Instrument (DESI) – Taking Data!

The 4-month survey validation (SV) phase started Dec.2020

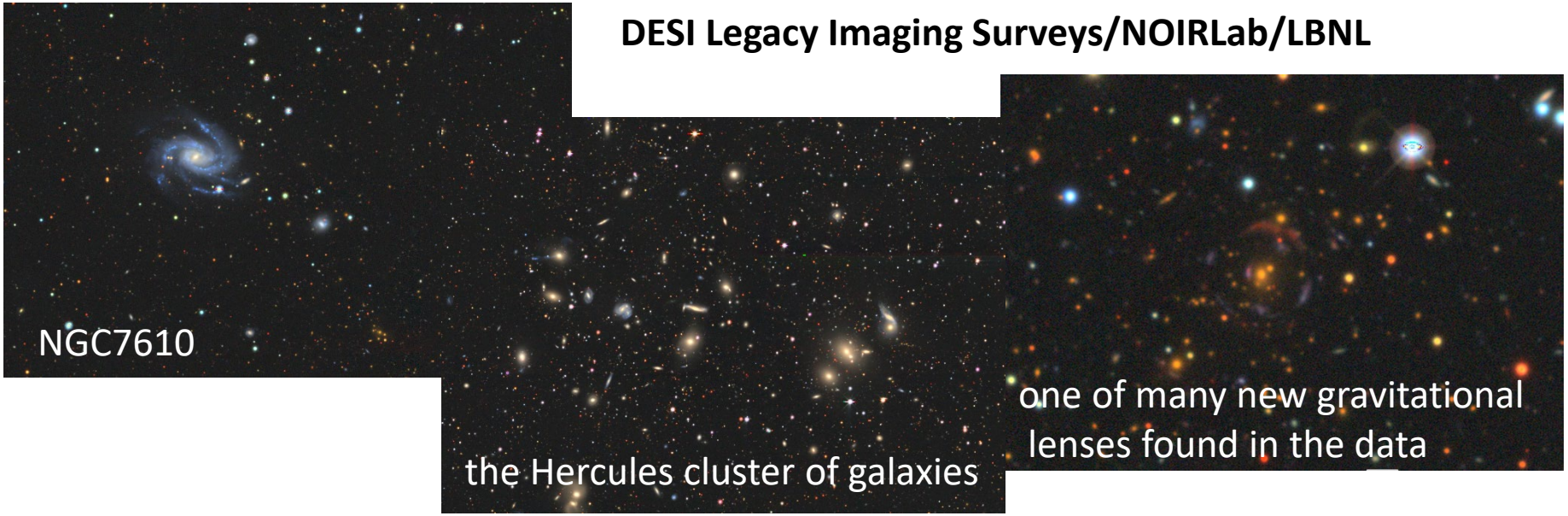
- 1044 science exposures through mid-February (each with ~5,000 spectra). Analysis so far indicates DESI will achieve TDR in performance and survey depth/parameters.
- Sky map of where DESI is observing target classes during SV



Dark Energy Spectroscopic Instrument (DESI) – Delivering Data!

- Imaging survey public data release DR9 – Jan. 2021
  - 2B objects from 3 public surveys which mapped 20,000 deg^2
  - for DESI target selection with many other studies possible
- See: legacysurvey.org/viewer
- HEP contributions included upgrade of MOSAIC camera on the Mayall and data processing at NERSC

DESI Legacy Imaging Surveys/NOIRLab/LBNL



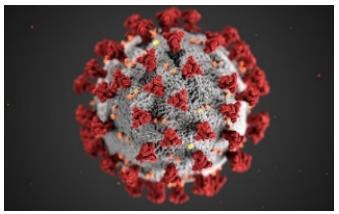
Vera C. Rubin Observatory

NSF (AURA) and DOE (SLAC) partnership w/private and international contributions

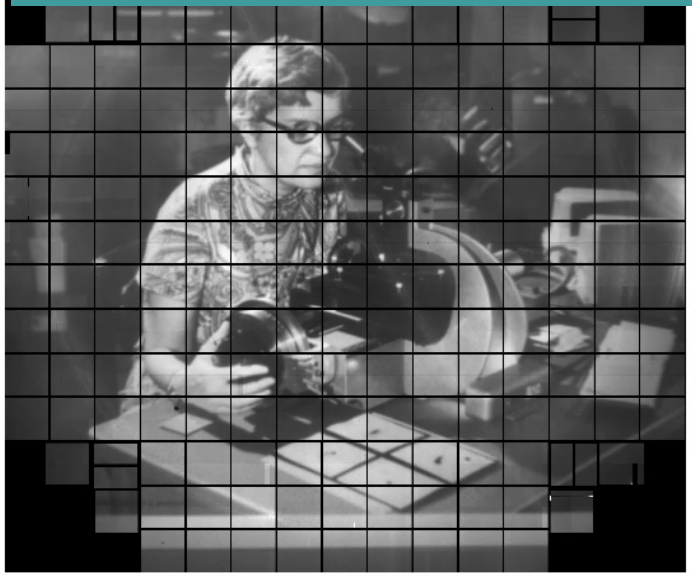
- Project: DOE responsible for the LSST Camera fabrication & commissioning
- Facility Operations: 50/50 DOE & NSF split

4 primary science themes:

- Probing Dark matter and **Dark Energy**
- Mapping the Milky Way
- An Inventory of the Solar System
- The Transient Optical Sky



Pinhole camera 3.2Gpixel image of Vera C. Rubin



Delay due to covid-19 expected to be about a year (data-taking now 2024).

DOE's Legacy Survey of Space and Time (LSST) Camera

- **DOE** is responsible for the 3.2 billion-pixel **LSST Camera & related systems, a 413.3b Major Item of Equipment (MIE) Project ($168M TPC)**
  - **SLAC** (lead) + BNL, LLNL, universities
  - **France/IN2P3** contributions.

Fabrication:

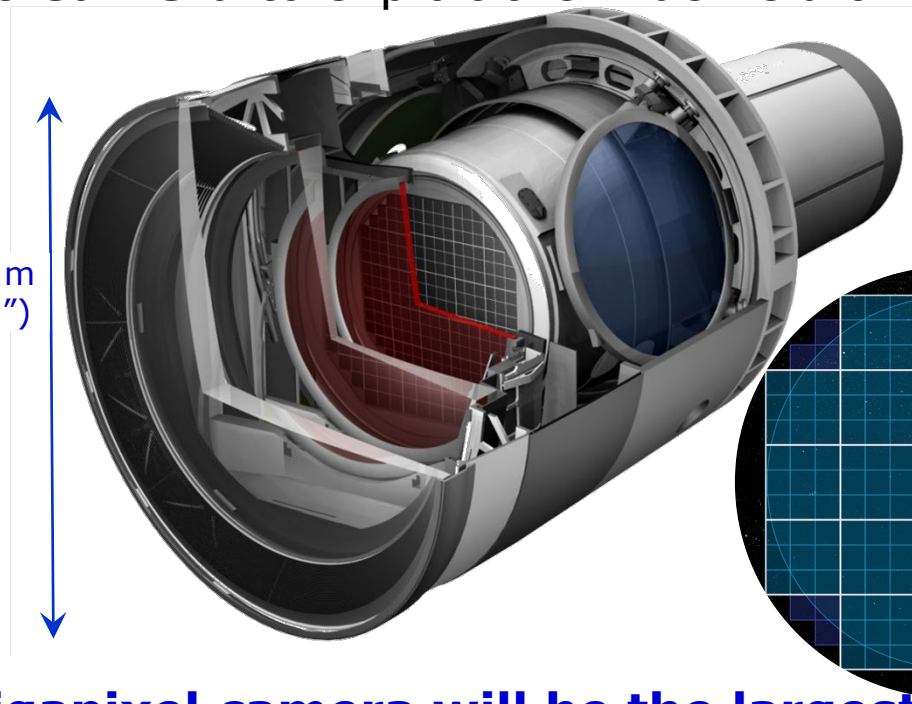
- **Camera project** efforts stopped in March 2020 (covid-19) and then slowly phased back to carry out required in-person efforts.
- It is now in the process of completing.
- Due to covid-19 delays & uncertainties, the project has been restructured to complete at the subsystem level (~ June 2021)
- Only remaining scope is filter completion

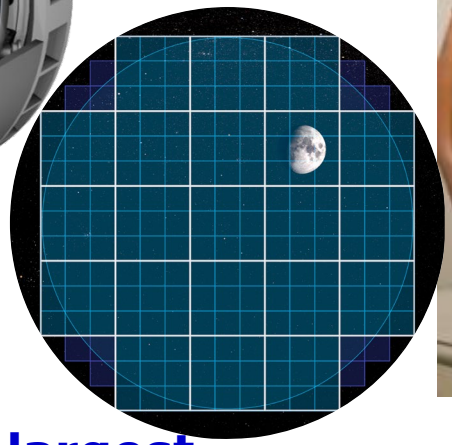
HEP Commissioning roles (on program funds)

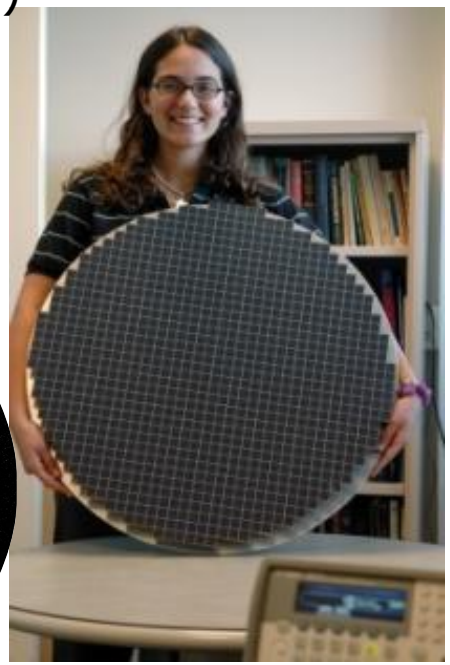
- Assembly and verification at SLAC
- Camera is expected to ship to Chile in Feb. 2022 and be ready for installation and commissioning on telescope ~ July 2022

The LSST Camera – What's So Special?

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







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

There are six optical filters, five of which are resident in the camera on any given night.

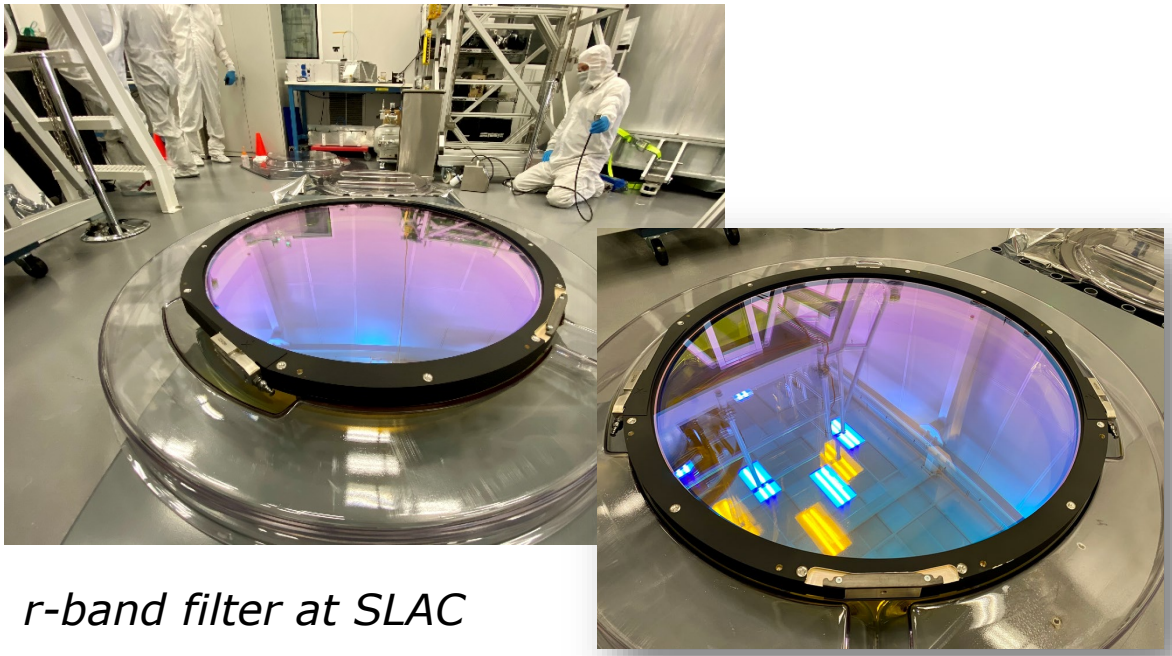
3.2 GigaPixel Camera

- 63 cm focal plane
- 2 second readout (fast!)
- 3060 kg
- 1.65 M front Lens
- 6 filters 0.3 – 1.1μ
- 189 sensors in 21 rafts

Camera Status

Camera Project: remaining scope is the completion of the 6 filters.

- Filter coating – 4 complete and 5th in process. Expect all 6 to be complete by May.
- The i-band and z-band have arrived at LLNL. The r-band filter has arrived at SLAC and is secured in its container for temporary storage until ready to be stored in the filter storage box received from IN2P3.



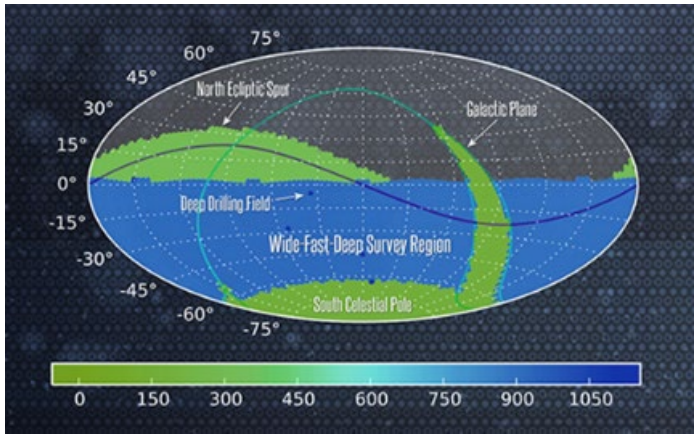
r-band filter at SLAC

Camera Commissioning:
All hardware is in Chile
Due to some concerns regarding the refrigeration system, alternate concepts are being investigated in parallel.

Rubin Observatory: Facility Operations Planning

The Rubin Observatory will conduct a 10-year deep, wide, fast, optical imaging Legacy Survey of Space and Time (LSST) using DOE's LSST Camera & the Simonyi Survey Telescope

- 18,000 sq deg, 6 filter bands, ~ 1000 visits per sky patch
- Will produce a catalog of more than 20 billion galaxies & 17 billion stars
- Tens of billions of events will be detected and alerted on in real-time



Planning is well underway

- Funding ramp-up started FY2019
- DOE & NSF will provide 50/50 support
- DOE-supported efforts are primarily:
  - Camera maintenance and operations
  - US Data Facility (USDF)

In the coming year the team plans to

- Prepare for Dec. 2021 proposal including the detailed operations plan
- Deploy the Dark Energy Science Collaboration data challenge 2 (DC2) simulated data in the Interim Data Facility (Google, cloud-based) as "Data Preview 0". DP1 & DP2 will use commissioning data
- Carry out the USDF planning & finalize the international in-kind contributions.

3 Rubin Data Facilities – in the US, France & UK

➔ **SLAC was selected to be the managing organization for the USDF in Oct. 2020 and will will carry out all the planned functions.**

- The Data Facility is fully integrated into the NOIRLab and SLAC partnership to carry out the Rubin Operations plan and deliver all the data products to all the researchers and collaborations.

Images will be transferred directly to the USDF at SLAC where they will be processed within 60 seconds of observation.

The USDF is the primary data facility and will:

- Generate Transient Event Alerts that will be released publicly after vetting.
- Generate "Prompt Data Products" that will be available to data rights holders.
- Archive all the data, and provide a Data Access Center

The 3 Data Facilities will carry out the processing for the annual data release catalogs, distributed as USDF (25%), the French DF (50%), and the UK DF (25%).

Facility Operations: →International in-kind contributions

→International in-kind contributions in exchange for data rights & access during the 2-year proprietary period (same rights as US and Chilean scientists) are being planned. →Scientific partnerships.

Priority for contributions:

- Offsets to US operations costs (these are minimal)
- Enhancements for US science, esp. Rubin/LSST science (majority).
  - Contribution to science collaboration software, simulations, data analysis tools
  - Contributing telescope time to US scientists
  - Contributing other data sets or appointments to collaborations that the US otherwise doesn't have access to.

Process is underway: Rubin operations team is carrying out process on behalf of DOE & NSF.

- Fall 2020: Detailed proposals submitted
  - Received 33 proposals with 831 PI's (each PI gets to bring 4 junior people).

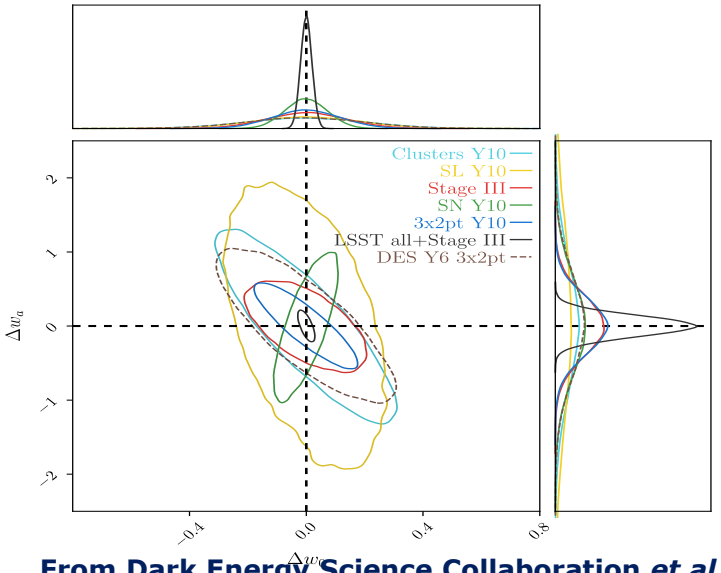
- Contribution Evaluation Committee is carrying out assessments.
- Following needed modifications and approval by the Management Board, the team will present the plan to DOE & NSF for approval in spring 2021.
- **Agencies will make final decisions on international in-kinds** and carry out (or delegate) the official agreements; goal is completion of agreements by the end of 2021.
- Annual International Resource Board will assess and update contributions

Rubin Observatory Legacy Survey of Space and Time → Dark Energy Science Collaboration (DESC)

Scientific Research - Both NSF and DOE will support community efforts

- **DOE's research efforts are organized through DESC**; planning and readiness activities are continuing.

Collaboration ~ 1000 members;
> 225 full members; from 15 countries



From Dark Energy Science Collaboration *et al.*, 2018.

Data enable study of the nature of Dark Energy via complementary probes:

- SNe Ia's as "standard candles"
- Baryon acoustic oscillations as a "standard rulers"
- Studies of growth of structure via weak gravitational lensing
- Studies of growth of structure via clusters of galaxies

These tests also provide constraints on the nature of inflation, modifications to GR, the masses of neutrinos, the nature of dark matter.

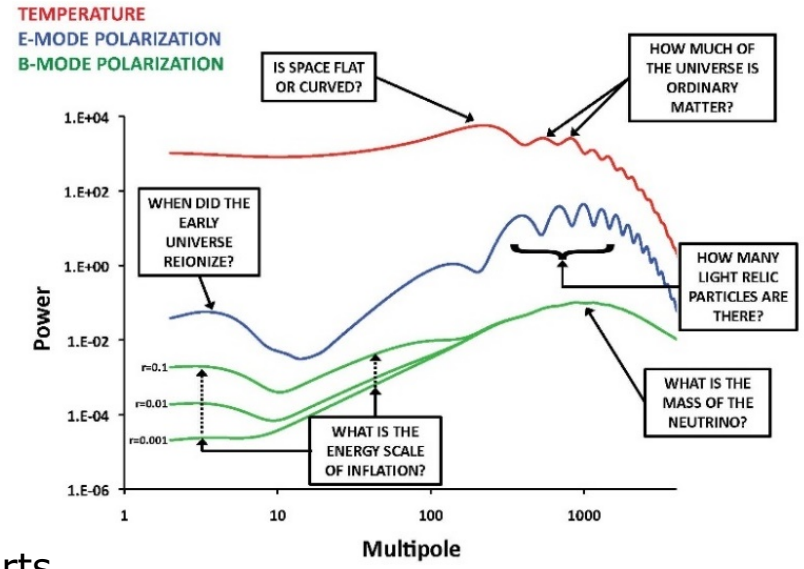
Connections with Rubin Observatory

- Formalized an agreement for the Observatory to use DESC's Data Challenge 2 simulations in it's Data Preview 0 planning & effort.
- Contributing to observing strategy planning
- Possible opportunities to contribute to technical validation of Rubin Observatory during Commissioning.

Cosmic Microwave Background – Stage 4 (CMB-S4)

CMB-S4 recommended by P5 in all scenarios
- Intended as HEP/Cosmic Frontier's next flagship project

Goal: cross critical science thresholds



Highlights: 2 sites, Chile & South Pole

- Chile: 2 large aperture (6m) telescopes
  - Deep & wide N_{eff} & Legacy Survey ~60% of sky
- South Pole: 1 large (5m), 18 small (0.5m)
  - Ultra-deep survey ≥ 3% of sky + delensing
- Total 500,000 cryogenic sensors, superconducting readout
  - Scale-up > x10 of current CMB ground based efforts

The Science

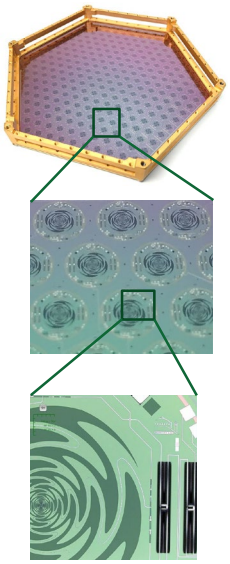
Science	Stage 2	Stage 3	Stage 4	Top Level goal for CMB-S4
Inflation "r"	≤0.1	≤0.01	**≤0.001**	Detect/rule out classes of inflationary models
s(Neff)	0.14	0.06	**0.03**	Detect/rule out light relic particles w/ spin
s(Mn)	0.15eV	0.06eV	**0.02eV**	3s detection
# detectors	~1000	~10,000	**~500,000**	Deployed on multiple telescopes
Sensitivity (mK^{-2})	10^5	10^8	**10^8**	2° to 1' angular scales

CMB-S4 Status at DOE

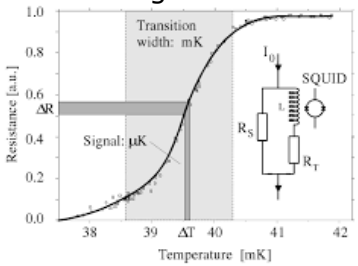
Huge discovery potential recognized by 2014 P5 as a community priority
- Envisioned as a DOE-NSF project

- **Aug.2019** Project received Critical Decision 0 (CD-0)
- **Aug.2020**, LBNL chosen as DOE Lead lab
  - Will manage DOE/HEP roles & responsibilities
    - Currently developing project management, personnel, R&D plan, cost, & schedule in association with U. Chicago (has 2019 NSF MSRI-1 award)
- **Dec.2020, FY21** budget appropriation provides $6M for R&D and project management
  - Congress approved it as a Major Item of Equipment (MIE) "project start" by providing $1M (of the $6M) in equipment "EQU" funding.

Detector wafers
~1000 pixels per waver



Transition Edge Sensors

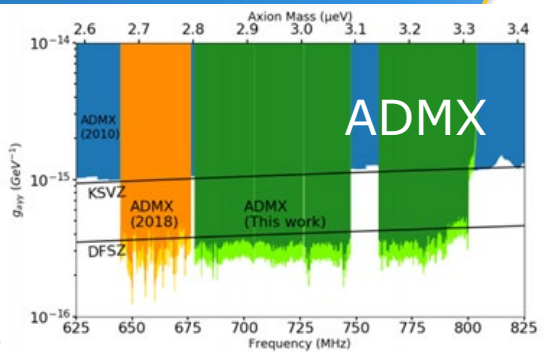


Short term challenge: slow ramp up of funding compared to Project's request; limits the planned R&D, especially on detectors and readout

Longer term challenge: Synchronizing DOE & NSF roles. Experience with partnerships on Rubin/LSST and HL-LHC will prove useful

Direct Detection of Dark Matter

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



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

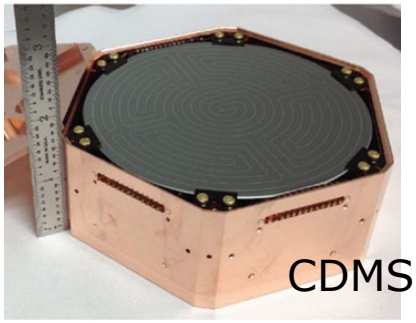
ADMX-G2 axion search (μeV-meV mass) operating at UW

LZ at Homestake Mine in South Dakota

- Dual phase liquid Xe WIMP search; ~10-1000 GeV mass
- Project fabrication complete; Now in commissioning; Physics data-taking starts summer 2021.

SuperCDMS-SNOLab in Canada (HEP+NSF partnership)

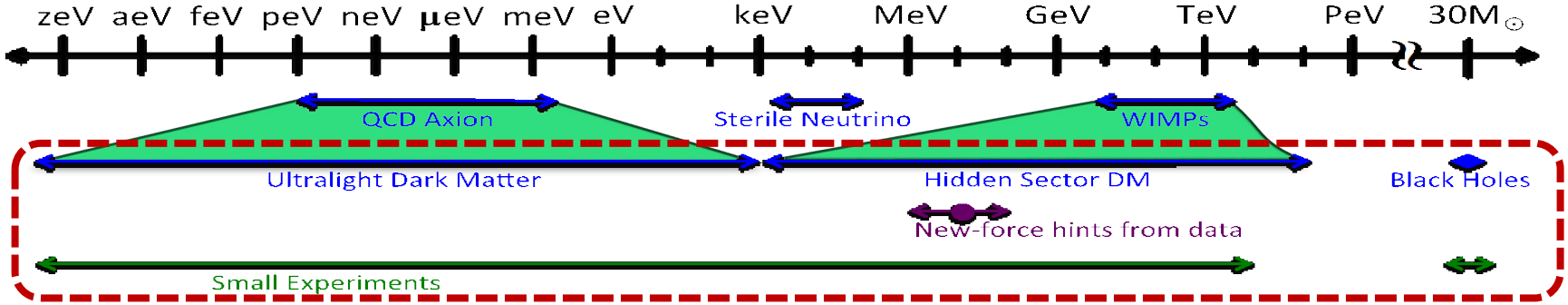
- Cryogenic solid-state crystal WIMP search; ~1-10 GeV mass
- Project fabrication delays due to cryostat procurement & covid-19; Rebaseline is planned → CD-4 completion in FY23.



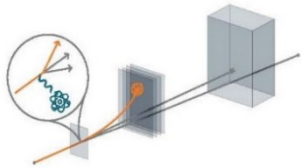
Dark Matter New Initiatives (DMNI) for small projects

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

- Recent theoretical advances and development of new technologies opened new avenues to explore dark matter

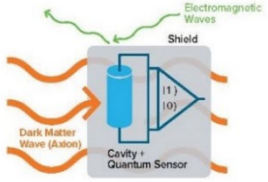


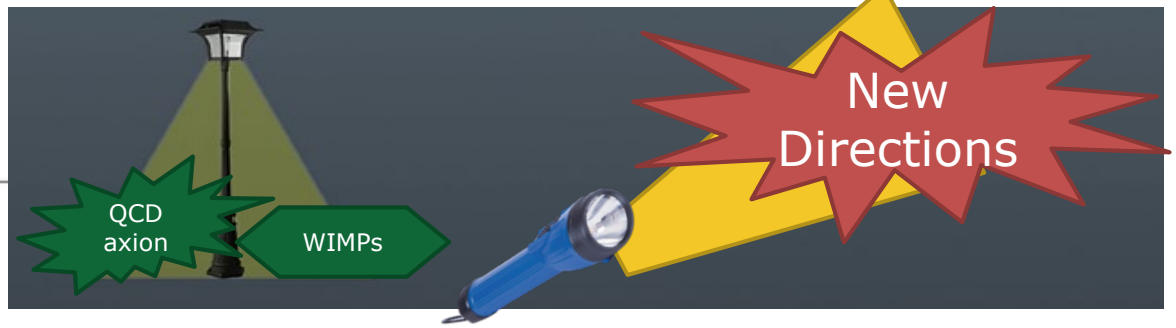
PRD 1
Create and Detect DM at Accelerators.



PRD 2
Detect Galactic DM Underground.

PRD 3
Detect Wave DM in the Laboratory





➢**2017** Community Workshop, https://arxiv.org/abs/1707.04591

➢**2018-2019**: Basic Research Needs (BRN) study developed 3 Primary Research Directions (PRD) https://science.energy.gov/hep/community-resources/reports/

Dark Matter New Initiatives (DMNI) – Concept Studies

➢**2019-2020: Funding Opportunity Announcement (FOA); Six proposals aligned with the PRD's selected to develop concept & execution plans for potential small projects**

Funds are primarily for engineering, M&S and not for scientist (research) support. We assume the team has adequate research support and will transition to this effort.

→ **Can consider research support if scientists aren't already HEP-funded.**

Cosmic Frontier:

- **ADMX Extended** (axions 2-4GHz), 9-17 μeV, A. Sonnenschein (FNAL)
- **OSCURA** (low noise "Skipper" CCD detector) 1MeV-1GeV, J. Estrada (FNAL)
- **DM-Radio** (axion search), <μeV, K. Irwin (SLAC)
- **TESSERACT** (Multiple detectors, w/TES readout), >10 MeV, D. McKinsey (LBNL)

Intensity Frontier (accelerator based)

- CCM Beam Dump exp at FNAL, ~1-40 MeV, R. van der Water (LANL)
- Light Dark Matter Experiment (LDMX) ~ 10-300 MeV, T. Nelson (SLAC)

Following completion of Concept & Execution plans, concept will be reviewed before HEP considers advancement to small project fabrication phase.
➔Based on the case for the project, design, priorities, and funding availability, we may not move all to fabrication.

Opportunity: Joint DOE-NASA RFI

On January 21, DOE Office of Science, jointly with NASA Science Mission Directorate, released a **Request for Information (RFI) related to high energy physics and space-based astrophysics.** Responses were **due March 8th.**

- The RFI is to gather information from the community in **3 specific, focused areas aligned with the science goals of both of the program offices**
  - including the scientific and technology benefits and obstacles, how it will make use of each agency's capabilities, infrastructure and resources, etc.
- The information received will inform DOE and NASA regarding the potential development of new mutually beneficial partnerships and collaborative activities.

The 3 focused areas are:

1. Sensitive radio telescopes or sensors on the Moon's far side to explore the early eras of the universe or test the standard cosmological model
2. Small experiments to carry out space-based probes of fundamental physics in a microgravity environment of the International Space Station
3. Enhance or extend the dark energy science reach of data from the Vera C. Rubin Observatory, the Nancy Grace Roman Space Telescope and the Euclid observatory when considered together, including development of a common library of simulations, &/or capabilities to enable joint data processing & analysis.

Opportunity: Joint DOE-NASA RFI

RFI:
https://www.federalregister.gov/documents/2021/01/21/2021-01236/request-for-information-related-to-high-energy-physics-and-space-based-astrophysics
Responses were **due March 8th.**

Status: The responses to the RFI are in and the agencies have started reading them and will meet soon to discuss them.

This RFI is part of a wider DOE/NASA effort to investigate collaborative activities as part of an MOU signed in Oct. 2020
See https://www.energy.gov/articles/department-energy-and-nasa-sign-memorandum-understanding

HEP COVID-19 Considerations & Plans

- We do not know how/if the pandemic will evolve – continue monitoring
- Our labs and projects have developed plans several different scenarios, with updates as needed.

Operations:

- Mature experiments can mostly operate remotely with limited staff support on site - so are in reasonably good shape.
- Experiments just starting operations (e.g. LZ at SURF, DESI at Kitt Peak) faced larger delays & challenges as they worked to update procedures and gain access.

Projects:

- Several projects (e.g. LSST Camera, LZ) were able to finish fabrication and push some tasks to commissioning/operations, due to the uncertainties about the pandemic. Typical expected delays for science are 6 months to 1 year.
- Others need to be rebaselined, with timing adjusted for each circumstance.

HEP COVID-19 Considerations & Plans

Research:

- Without bridge support for students and post-docs, our R&D workforce pipeline is threatened with disruption:
  - Delayed or postponed hires at each career stage; loss of University TA's.
  - New offers reduced, especially for international students
- Net result is reduced R&D workforce to support experiments and projects.

Mitigations:

- PI's have been notified that they have significant flexibility within existing grants to re-plan their scope of work to accommodate tasks that have been cut short or delayed due to covid, including extending support for junior scientists, which is one of our highest priorities.
- We have been working with PI's on a case-by-case basis to address these issues as needed.

➔The need to continue support for existing students and postdocs **may impact the availability of funds** for new proposals and renewal proposals.

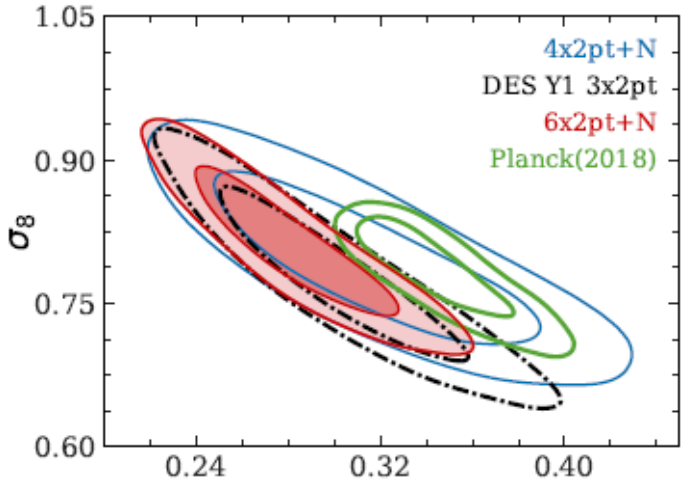
Dark Energy Survey (DOE/NSF)

DARK ENERGY SURVEY

6-year imaging survey of 5100 sq-deg completed 2019

- DOE/Fermilab 570Mpix Dark Energy Camera (DECam) operated on NSF's Blanco telescope at CTIO in Chile.
  - Over 320 science publications with world-leading constraints on dark energy (including submitted) (see plot upper right)
  - 84+ PhD's awarded through 2020

Y1 3x2pt WL & Y1 Galaxy Clusters

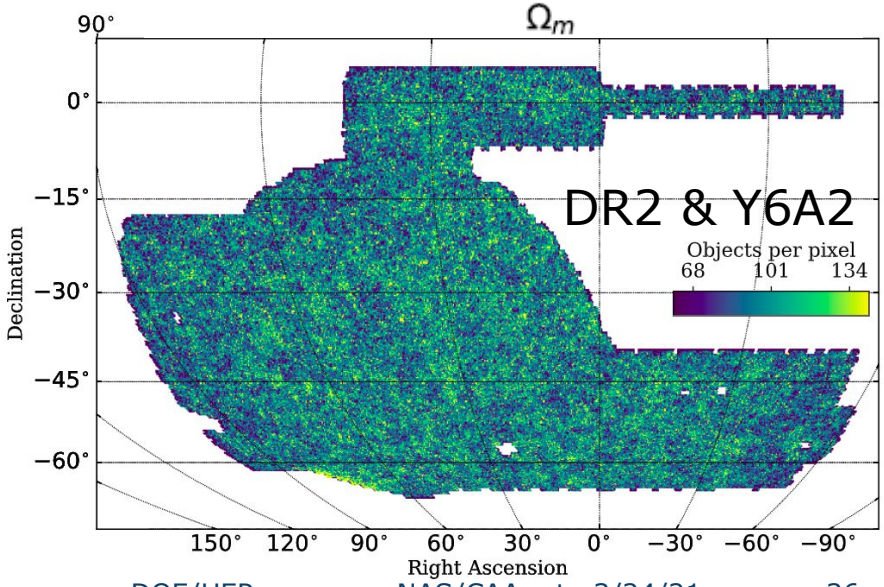


FY2021: Public Data Release 2 (Y1-Y6 data). 690M objects with unprecedented photometric, astro-metric precision & uniformity.

FY2022: Y1-6 data processing with cosmology-added ("Gold") data products

FY2023: Y1-6 Gold to Collaboration

FY2024: Y-16 Gold made public; Cosmology analyses complete

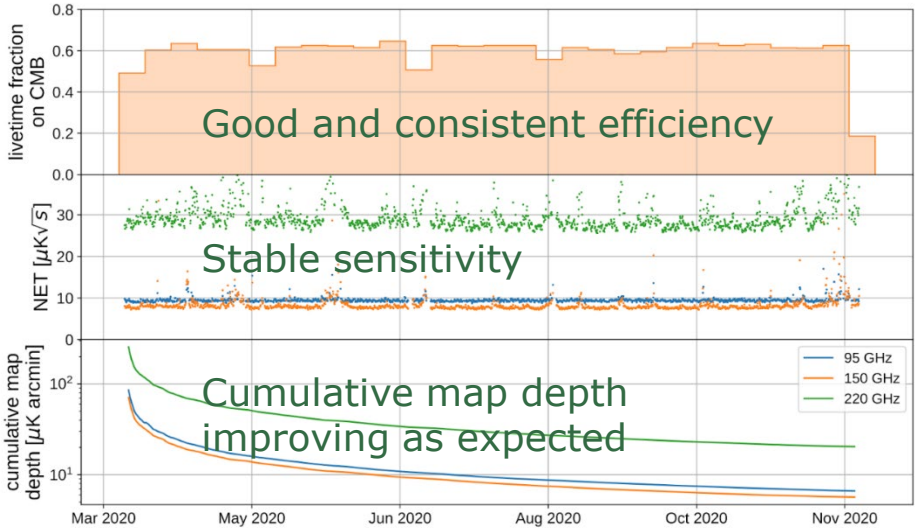


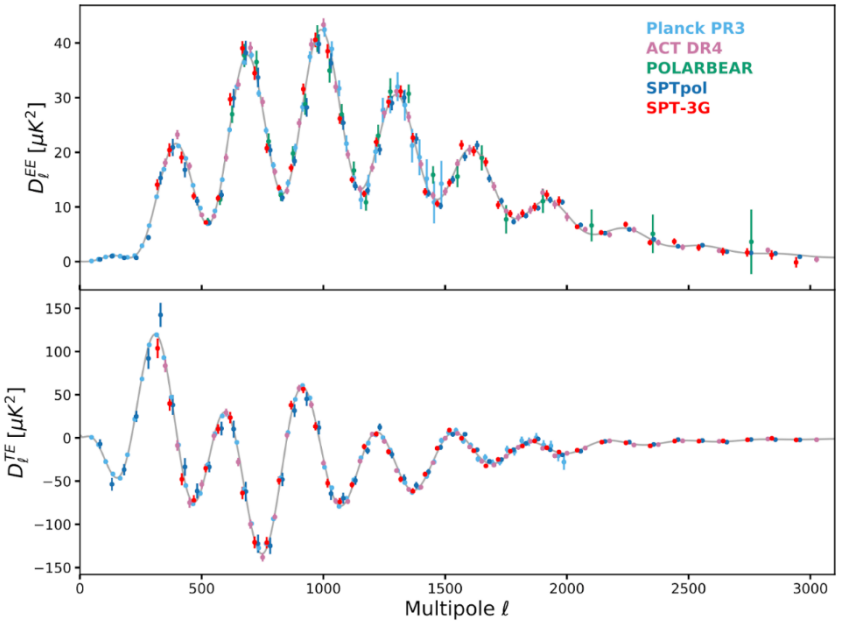
South Pole Telescope (SPT-3G)

NSF & DOE partnership
HEP supported major upgrade: fabrication of the 16,000-detector focal plane, greatly increasing sensitivity; now operations

Science goals:

- dark energy constraints from CMB lensing & galaxy clusters
- constraints on neutrinos and other light particles
- with BICEP/Keck, potential measurement of primordial gravitational waves.





First SPT-3G science publication

- Measurement of TE/EE power spectra with 2018 data

Dutcher et al.
https://arxiv.org/abs/2101.01684
Submitted to Physical Review D

←Survey started 2018; continues to operate smoothly with high observing efficiency

Exploring the Unknown

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

Operations continuing – no major covid-19 impacts

Fermi/GLAST - Large Area Telescope (LAT) (w/NASA)

- Space-based gamma-ray observatory, launched in 2008
- HEP/SLAC led the fabrication of the LAT; Continues to support critical efforts at the LAT Instrument Science Ops Center at SLAC

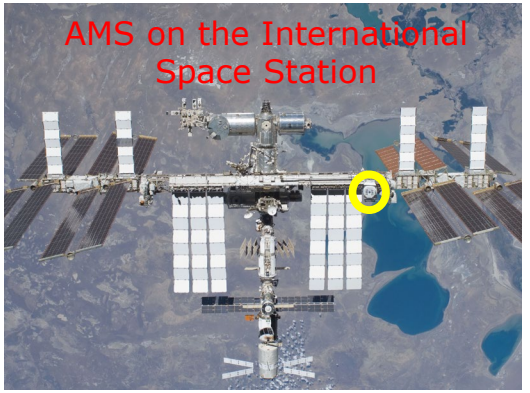
AMS *(w/NASA)*

- Launched and mounted on International Space Station in 2011
- DOE-HEP is responsible for management of the science program, led by Prof. Ting (MIT) and has roles in operations; Can continue through 2028+
- Multi-purpose particle-physics spectrometer detects cosmic-rays up to multi-TeV; search for anti-matter, dark matter etc.

HAWC *(w/NSF)*

Gamma rays and cosmic rays between 100 GeV and 100 TeV

- HEP operations support completed early FY2021.



Alpha Magnetic Spectrometer (AMS-02)

Physics: Search for antimatter, dark matter annihilations & new particle phenomena on International Space Station (ISS).

→ Multi-purpose particle-physics spectrometer detects cosmic-rays up to multi-TeV; uses permanent magnet

→ 95% of construction costs from Europe and Asia

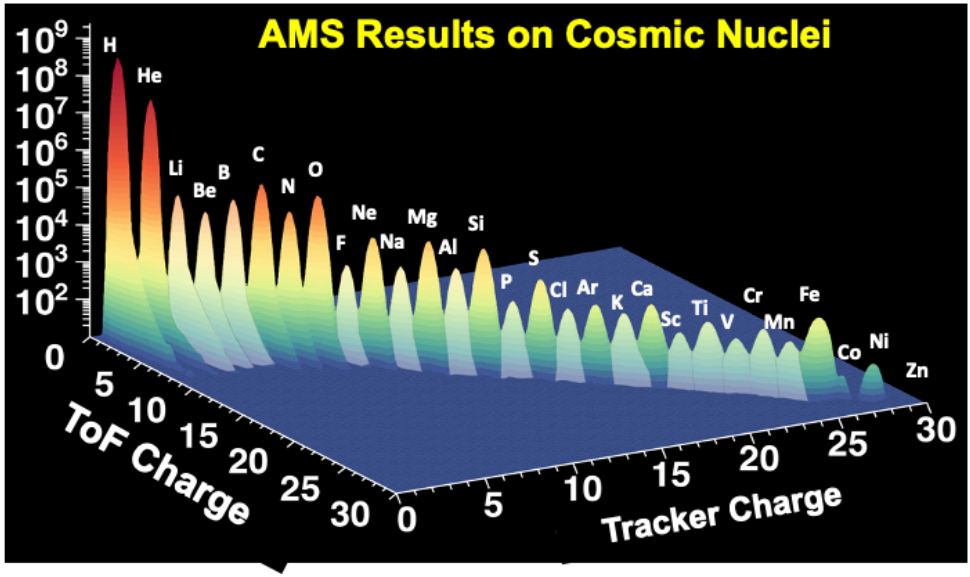
International Collaboration, with DOE/HEP leading US roles

- **DOE-HEP is responsible for management of the science program, led by Prof. Sam Ting (MIT) and has roles in operations**
- NASA provides the use of the ISS power, data, and mission management
- CERN hosts the Operations Control Center

Recent Highlights

~150 billion cosmic rays collected.

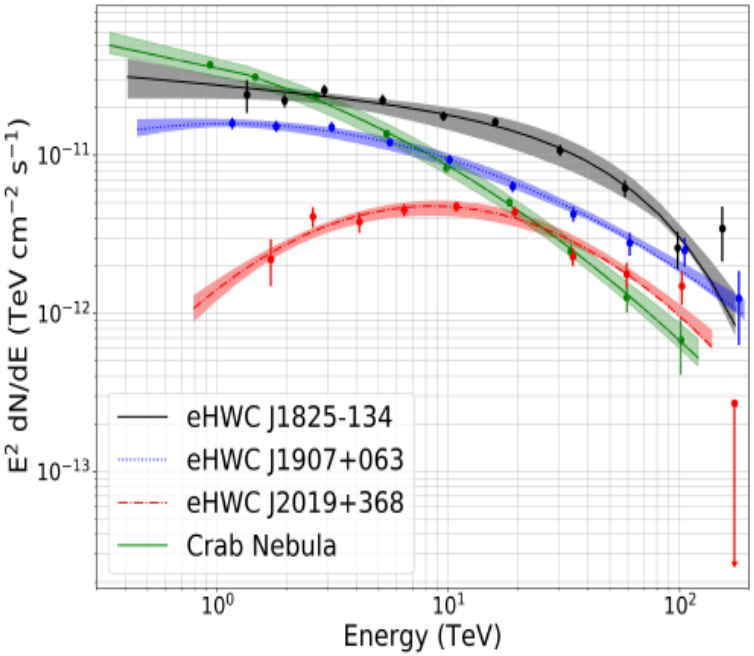
- **Recent EVAs (Fall 2019) by NASA to replace cooling system enables AMS to operate beyond 2028.**
- **High precision results on cosmic-ray elementary particle and nuclei fluxes, search for heavy antimatter and the origin of dark matter.**



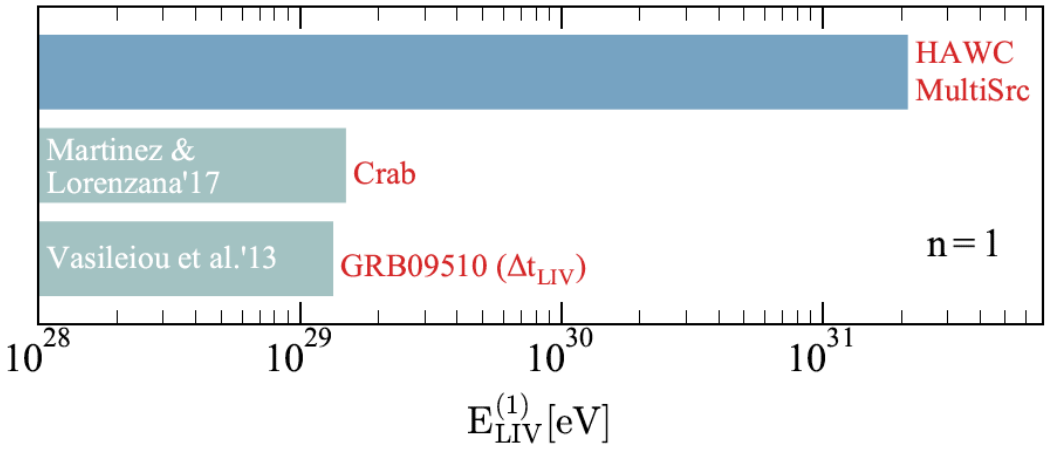
HAWC - Testing Lorentz Invariance

HAWC detects g-rays to >285 TeV which puts strongest constraints on Lorentz Invariance

- If Lorentz Invariance is violated, then g-rays above an energy threshold rapidly decay into e^+e^- pairs.
- HAWC's proof of the existence of g-rays >285 TeV provides ~ 2 orders of magnitude better constraints on superluminal Lorentz Invariance



PRL (Jan 2020)
K. Malone (LANL) corresponding author



PRL (Apr 2020)
P. Harding (LANL) corresponding author

U.S. DEPARTMENT OF
ENERGY | Office of Science

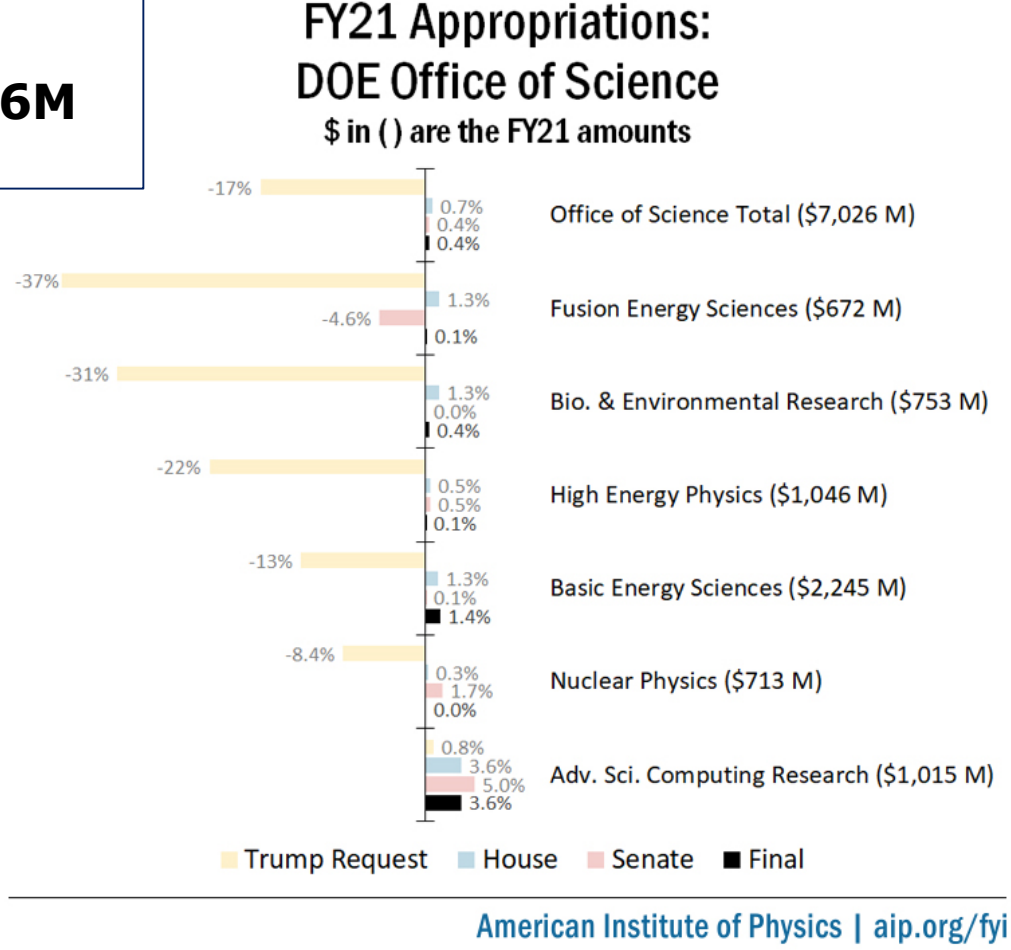
Budget

FY2021 Appropriation – SC, HEP

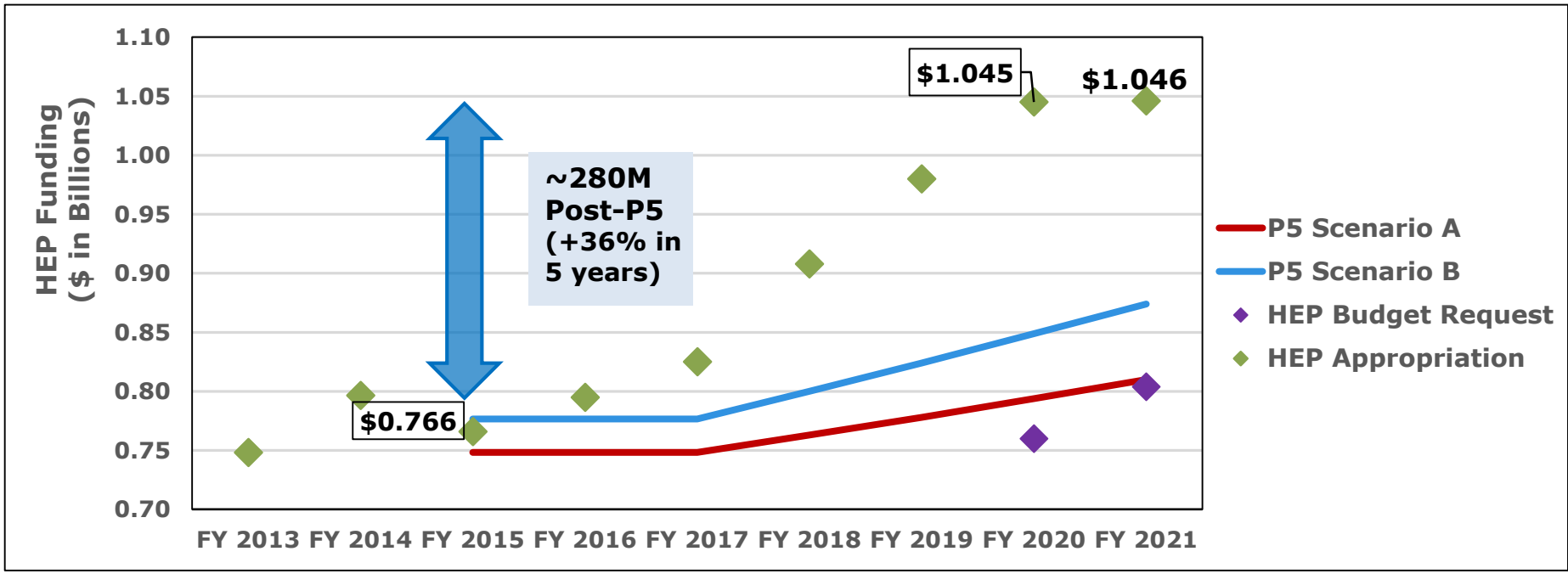
- **SC increase 0.4% from $7,000M in FY2020 to $7,026M in FY2021**
- **HEP increase of +0.1% from $1,045M in FY 2020 to $1,046M in FY 2021**

SC - New & Recent Research Initiatives applicable to HEP

- Integrated Computational and Data Infrastructure for Scientific Discovery
- Strategic Accelerator Technology Initiative
- Artificial Intelligence and Machine Learning: **$33M HEP, $100M SC**
- Microelectronics Innovation
- Quantum Information Science **$45M HEP, $245M SC**



HEP Budget: U.S. Congress Supports P5 Strategy



- U.S. Congress continues to show strong support for executing the P5 strategy, and for accelerating the pace of projects by providing the funding needed.

FY 2021 Appropriation - HEP

HEP Funding Category (in $K)	FY 2019 Actual	FY 2020 Actual	FY2021 Request	FY 2021 Appropriation	FY 2021 Appropriation - FY 2020 Actual	FY 2021 Mar AFP
Research	380,847	389,646	328,906	409,370	19,793	408,212
Facility & Exp. Operations	260,803	317,310	285,725	303,130	-14,799	304,288
Projects	338,350	338,044	203,500	333,500	-3,994	333,500
Total	**980,000**	**1,045,000**	**818,131**	**1,046,000**	**1,000**	**1,046,000**

FY21 QIS = $44M, AI/ML = $33M

FY 2021 Budget Appropriations

- Continued **strong Congressional support.**
- **Increased funding for new or recent initiatives: QIS, AI/ML, Accelerator R&D, and MicroElectronics**
- **Appropriations specified budget amounts in a number of areas, thereby constraining & leaving little flexibility in other parts of the budget.**
  - Increased funding for Line-item construction, Initiatives, for CMB-S4 MIE, and for FACET User Facility, DESI, LZ and Vera C. Rubin Operations. However, the overall budget was up only $1M.
  - To keep a strong Research program as recommended by our Committee of Visitors and other community groups, other discretionary parts of our budget were reduced.

FY 2021 Appropriation Language for HEP, related to Cosmic Frontier

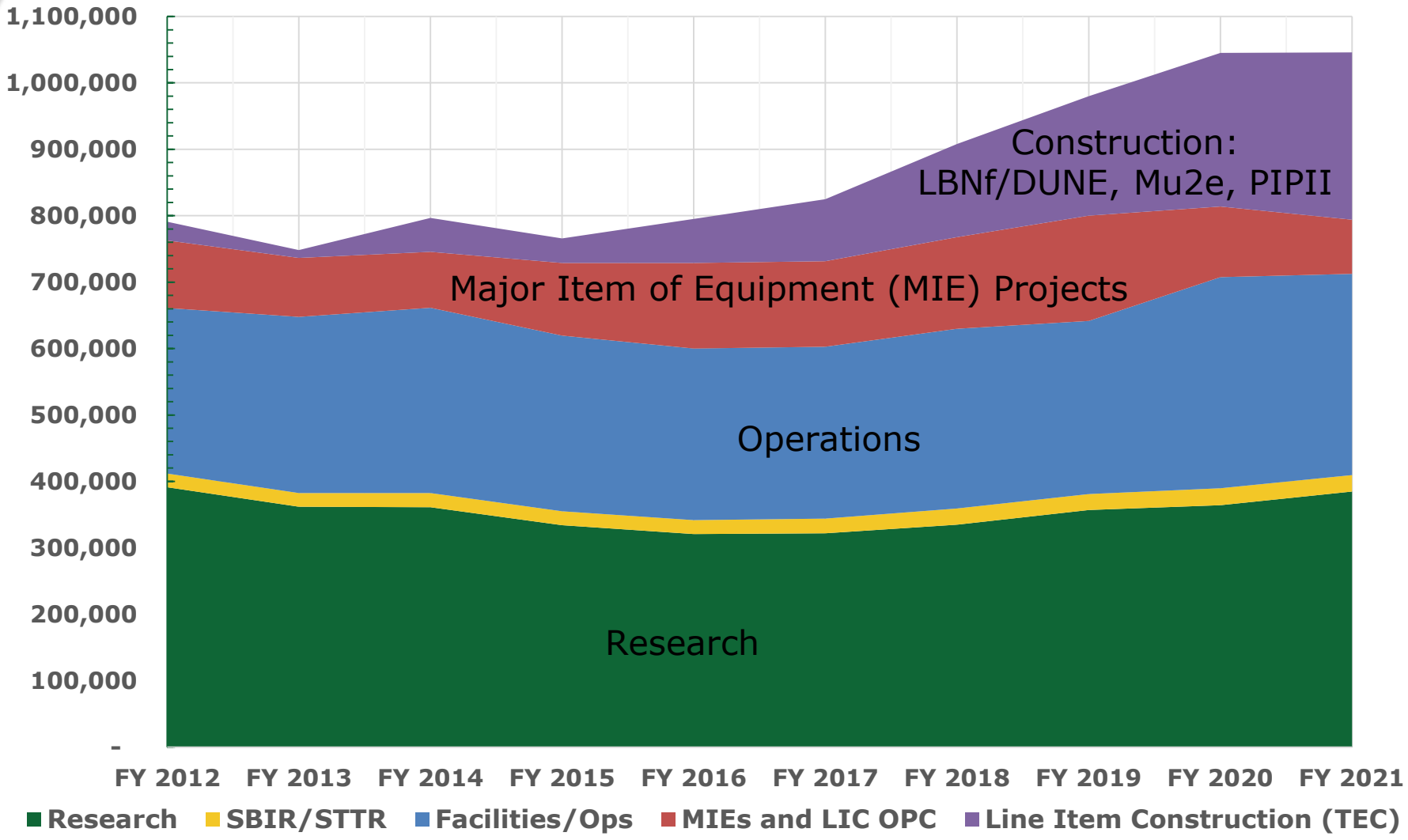
HEP is directed to provide:

- not less than $30M for the Sanford Underground Research Facility
- not less than $6M for **Cosmic Microwave Background-Stage 4** ($5M is R&D/planning)
- $12M for the **Dark Energy Spectroscope Instrument**; 6M for **LZ**
- not less than $18.5M for **Vera C. Rubin Observatory** operations

HEP Budget guidance:

- The agreement supports activities toward the completion of the **Large Synoptic Survey Telescope and Super Cryogenic Dark Matter Search** projects.
- The agreement notes the longstanding planning and contributions of resources by partner organizations with respect to data management on the **Vera C. Rubin Observatory**.
- The Department is directed to employ the computational expertise and existing capabilities in data management of the **Vera C. Rubin Observatory**, potentially in partnership with the national laboratories, to ensure the successful operation of this project and access for the broad research community.
- The Department is directed to brief the Committees on Appropriations of both Houses of Congress not later than 30 days after enactment of this Act on the status of the project, including plans for management of the data facility.
- The Department is strongly urged 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 Department is encouraged to fund facility operations at levels for optimal operations.

HEP Budget ($k) FY 2012-2021

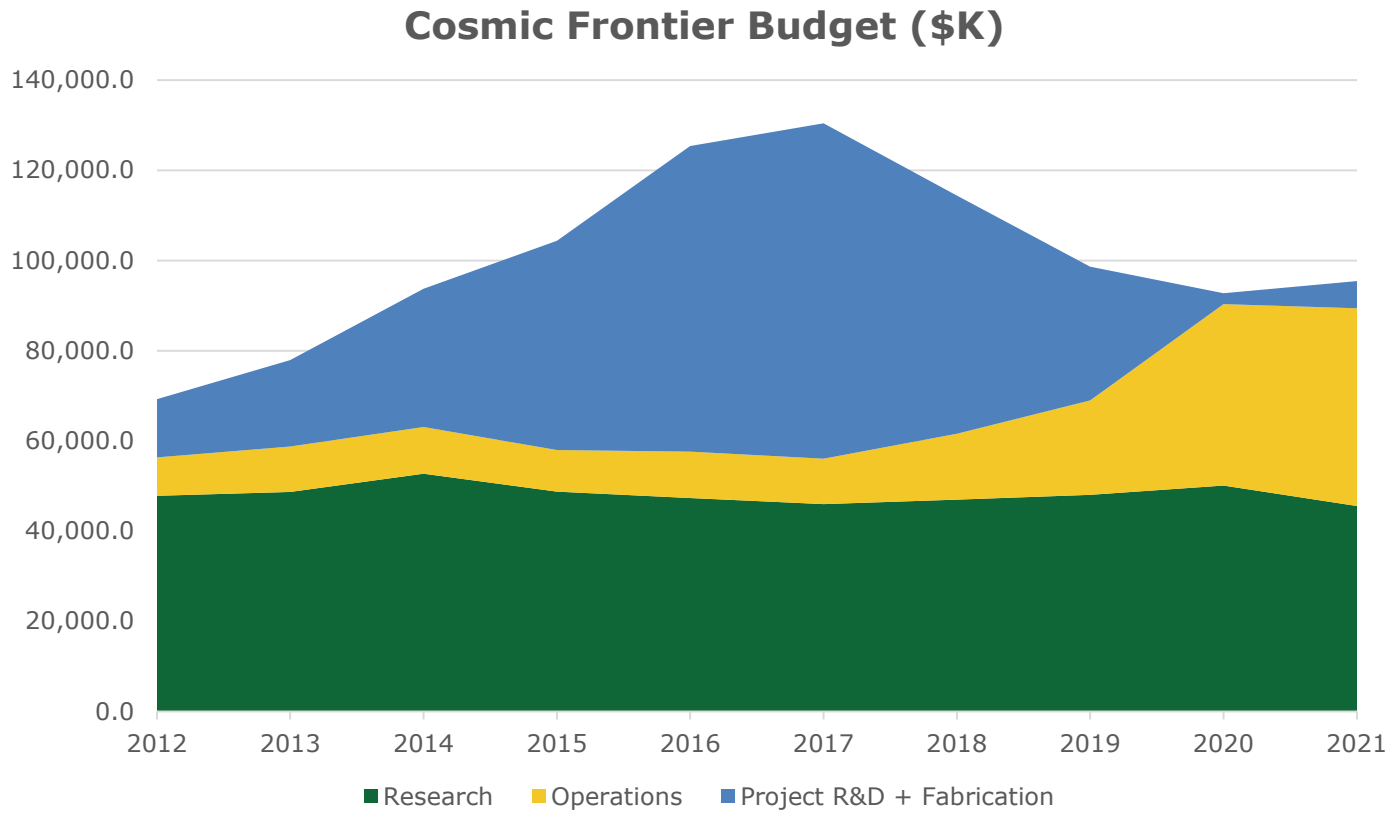


FY 2021 Funding – Cosmic Frontier

Cosmic Frontier ($K)	FY2019 Actual	FY2020 Actual	FY2021 Approp.
Research (Univ+Lab)	48,053	44,264	39,634
Research AI/ML		3,351	3,920
Future R&D	3,265	2,480	2,000
Facility & Exp Operations	20,957	40,235	43,897
Projects	26,350	2,450	6,000
DESI	*9,350*	*0*	*0*
LZ	*14,450*	*0*	*0*
SuperCDMS	*2,550*	*0*	*0*
CMB-S4	-	*2,450*	*6,000*
Office support	3,667	4,181	4,436
SBIR/STTR	2,869	3,524	
Total	**105,161**	**100,485**	**99,887**

- **Research:** World-leading research efforts in support of design and optimization on dark matter and dark energy experiments in their fabrication and commissioning phases, R&D and planning for CMB-S4, planning for future experiments.
- **Operations:** Commissioning and facility operations planning for LSST/Rubin, commissioning and operations for LZ, operations for DESI, pre-operations activities for SuperCDMS-SNOLAB. Support for the currently operating experiments will continue.
- **Projects:** CMB-S4

Cosmic Frontier Budget History (FY12-21)



Projections:

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

International Partnerships

SC Programs' international cooperation currently operates under Office of Science International Agreements with countries and partner entities.

- Many international collaborations are through our National Labs, with agreements approved by DOE/SC.

Principles & Goals for international partnerships

➔ *pursue mutually beneficial collaborations as scientific partners that advance and accelerate scientific discovery*

- Parity in intellectual and financial contributions
- Scientific credit
- Respect of intellectual property rights
- Openness, transparency, respect for individuals

Science and Security Landscape

Legislation and Policy:

- **Sec. 1746, FY 2020 National Defense Authorization Act**: Directs OSTP to create an interagency working group "to protect federally funded research and development from foreign interference" and establishes a National Academies Roundtable
- **Sec. 223, FY 2021 National Defense Authorization Act**: Establishes funding disclosure requirements, standardization, and details consequences
- **National Security Presidential Memorandum-33** on strengthening the security and integrity of America's research enterprise

Government Reports:

- NSF-commissioned report on research security by the independent JASON group
- Senate Homeland Security and Governmental Affairs Permanent Subcommittee on Investigations: hearing and report on *Threats to the U.S. Research Enterprise from China's Talent Recruitment Plans*
- GAO report: *Agencies Need to Enhance Policies to Address Foreign Influence*
- White House National Science and Technology Council: *Recommended Practices for Strengthening the Security and Integrity of America's Science and Technology Enterprise*

Science and Security Landscape

DOE Actions

- **Coordinated review and oversight:** DOE leadership issued a policy memo on international S&T Engagement (2018)
  - Established a coordinated advisory body to identify and manage potential risks associated with international research collaboration
  - Developed a Science and Technology Risk Matrix for DOE Laboratories to guide and manage the following:
    - Foreign engagements
    - Cooperative research and development agreements
    - Strategic partnership projects
    - Official travel
    - Foreign national access
- **Restriction and Prohibition:** DOE issued a directive prohibiting DOE employees and contractors from participating in certain Foreign Government Sponsored Talent Recruitment Programs and restricting participation in certain foreign government sponsored or affiliated activities.
- **Continued and close coordination** with the White House and the interagency, allies and partners, as well as engagement with the research community regarding the development and implementation of new requirements.

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Scientific Research Support

Research Support - Priorities

DOE/HEP selects significant and coherent roles and responsibilities on the P5 portfolio of projects, facilities and experiments that are directly in line with our program and priorities and that make use of our capabilities and infrastructure.

→We works proactively with labs & university community to carry out these roles.

- Emphasis is placed on supporting science collaborations in all stages of an experiment - project's design, fabrication and operations & to plan and carry out data analyses to deliver the best science.

Research funding (at labs or university grants) supports a scientist's effort (usually part of a Collaboration) in carrying out all phases of an experiment (i.e. not just building or data analysis).

<u>Priority</u> is to provide research support for efforts that are directly in line with planning & carrying out the:

- DOE/HEP roles & responsibilities on our projects & operating experiments
- DOE/HEP priority science topics that were the basis for our participation.

Research Funding Opportunities - for scientists on HEP Experiments & to carry out Theoretical Studies

All scientific research efforts are subject to competitive peer review.

- University grants (new or renewal) are typically for 3 years.
- DOE Lab Research Program reviews are typically held every 4 years (Cosmic Frontier is June 2021)

https://science.osti.gov/hep/Funding-Opportunities

Funding Opportunity Announcements (FOA) are geared primarily towards PhD scientists at US laboratories or professors at US universities.

- **Research Opportunities in High Energy Physics** (universities, closed 1/26/21) https://science.osti.gov/-/media/grants/pdf/foas/2021/SC_FOA_0002424.pdf
- **Early Career Research** (closed 2/16/21) https://science.osti.gov/early-career
- **SC "Open Call"** [DE-FOA-0002181] - HEP uses this primarily for conferences and supplements
- **Quantum Information Science**
- **Traineeship in Accelerator Science & Technology**

➔University research funding typically support a professor's summer salary and provides support for postdocs, students and group expenses (computers, travel etc). Support for the PI's technical personnel and M&S to carry out their roles come from the Project or Experimental Operations Office.

Research Funding Opportunities

Workforce Development (WDTS) programs:
https://science.osti.gov/wdts

- **Office of Science Graduate Student Research fellowships (SCSGR)**
  - Supports grad student research at a DOE lab, 3 to 12 months, 2 calls per year
- **Science Undergraduate Laboratory Internships (SULI)**
  - Supports undergraduate research at a DOE lab, 10 to 16 weeks; 3 calls per year
- **Visiting Faculty Program (VFP)**
  - Summer research support for faculty/students from historically underrepresented institutions
- **Community College Internships (CCI)**
- **Albert Einstein Distinguished Educator Fellowship (AEF)**
- **National Science Bowl (NSB)**

HEP holds annual PI meetings - To brief and guide the HEP community on future FOAs and to provide a status and overview of the program.

- Opportunities for separate one-on-one sessions with program managers.
- The 2020 HEP PI meeting was held online August 24-26. All talks at https://www.orau.gov/heppi2020

Cosmic Frontier - HEP Research "Comparative Review" (Universities)

The 2009 Particle Astrophysics Scientific Assessment Group (PASAG) criteria is applied to Research; priority for critical HEP roles & science goals.

- Work as part of an HEP-style collaboration w/leadership & critical contributions to project, operations and data planning & analysis.

HEP uses merit review and then folds in programmatic factors of priorities for support, funding availability: Ensure PI's with near-term, critical roles/responsibilities are supported; Support all phases of project, operations, and data analysis.

	FY 2016		FY 2017		FY 2018		FY 2019		FY 2020	
Y1 request, available	$7.8/$4.3M		$7.6/$4.7M		$14.3/$5.4M		$5.2/$3.4M		$9.1/$4.9M	
	# Prop.	# PI's	# Prop.	# PI's	# Prop.	# PI's	# Prop.	# PI's	# Prop.	# PI's
# Received	43	62	31	49	30	49	23	36	30	51
Reviewed	36	55	26	43	28	47	20	33	30	51
Funded	21	25	18	26	23	33	18	26	23	36
Success Rate (%)	58%	45%	69%	60%	82%	70%	90%	79%	77%	71%

Cosmic Frontier
➔ Early Career Award Statistics (Univ + Lab)

Cosmic Frontier - Early Career awards	FY16	FY17	FY18	FY19	FY20
#Proposals Received	**13**	**13**	**16**	**17**	**16**
Proposals Reviewed Univ	7	8	11	13	11
Proposals Reviewed Lab	6	5	5	4	5
Funded Univ	**1**	**1**	**2**	**3**	**3**
Funded Lab	**0**	**1**	**0**	**0**	**0**

FY16:

Eduardo Rozo
Dark Energy

Anja von der Linden
Dark Energy

FY17:

Michael Schneider
Dark Energy

FY18:

Alexie Leauthaud
Dark Energy

Hee-Jong Seo
Dark Energy

FY19:

Tim Eifler
Dark Energy

Scott Hertel
Dark Matter

Elisabeth Krause
Dark Energy

FY20:

Hugh Lippincott
Dark Matter

Lado Samushia
Dark Energy

Michael Troxel
Dark Energy

Cosmic Frontier – Future Planning

Astronomy & Astrophysics "Astro2020" Decadal Survey

- Identify the most compelling science challenges and frontiers
- Develop a comprehensive strategy for 2022-2032.

-

DOE & NSF are charging the NAS to carry out an **Elementary Particle Physics (EPP) decadal survey**; starts in 2021

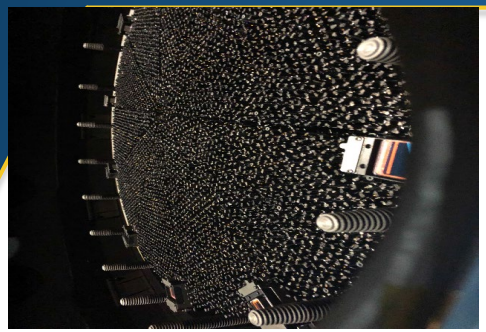
- Assess the current state of the field, identify the fundamental questions that motivate research and tools necessary to answer these questions in context of international landscape; consider cross-disciplinary aspects and societal benefits

"Snowmass" process led by APS/DPF, DPB for High Energy/Particle Physics community to identify science questions and directions for the coming decade. Process started summer 2019 and culminates in a workshop in summer 2022 (moved out a year due to covid-19 to ensure broad engagement and the fullest possible participation of the HEP community).

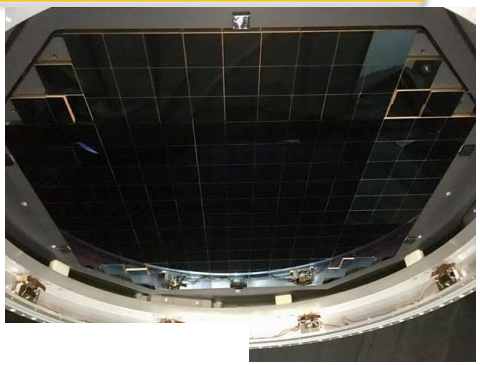
The multi-year community-driven processes culminates in the HEPAP **Particle Physics Project Prioritization Panel (P5)** to lay out a strategic plan.

- Input includes: Astro2020, European Strategy for Particle Physics, Japanese planning, "Snowmass" community workshops, NAS EPP, etc.

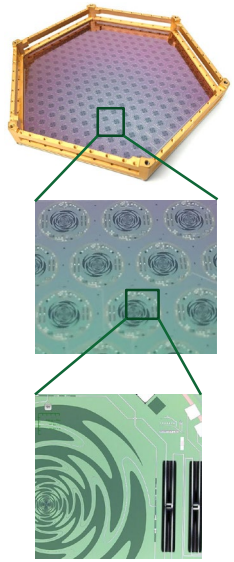
Summary



HEP continues to carry out the 2014 P5 strategic plan; Strong support from the scientific community and the Hill



- **DESI** has started it science survey operations (Dec.2020)
- **LZ** (dark matter) fabrication complete, now in commissioning
- **LSST Camera** nearly complete, Commissioning ongoing
- **Rubin Observatory** Facility Ops planning to be ready for data in 2024.
- **DESC** planning Rubin Observatory dark energy studies
- **CMB-S4** – LBNL selected as lead DOE lab; Approved as a fabrication project for DOE in the FY2021 budget; working towards planning for CD-1 and beyond.
- **DOE/NASA RFI on** focused, potentially collaborative areas.
- **Future Planning** – Astro2020, Snowmass → P5



→ **The future is bright!**

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