U.S. DEPARTMENT OF ENERGY | Office of Science

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

Astronomy & Astrophysics Advisory Committee (AAAC)

June 2, 2021

Kathy Turner, Cosmic Frontier Program Manager

Cosmic Frontier group members:

Karen Byrum (Detailee from ANL), ***Drew Baden*** *(IPA from U Maryland)*

OUTLINE

➔Update since the Jan. & Feb. meetings

- Budget
- Awards
- News from DES & DESI
- Project & Experiment Updates: Rubin/LSST, CMB-S4 + dark matter direct detection

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Budget

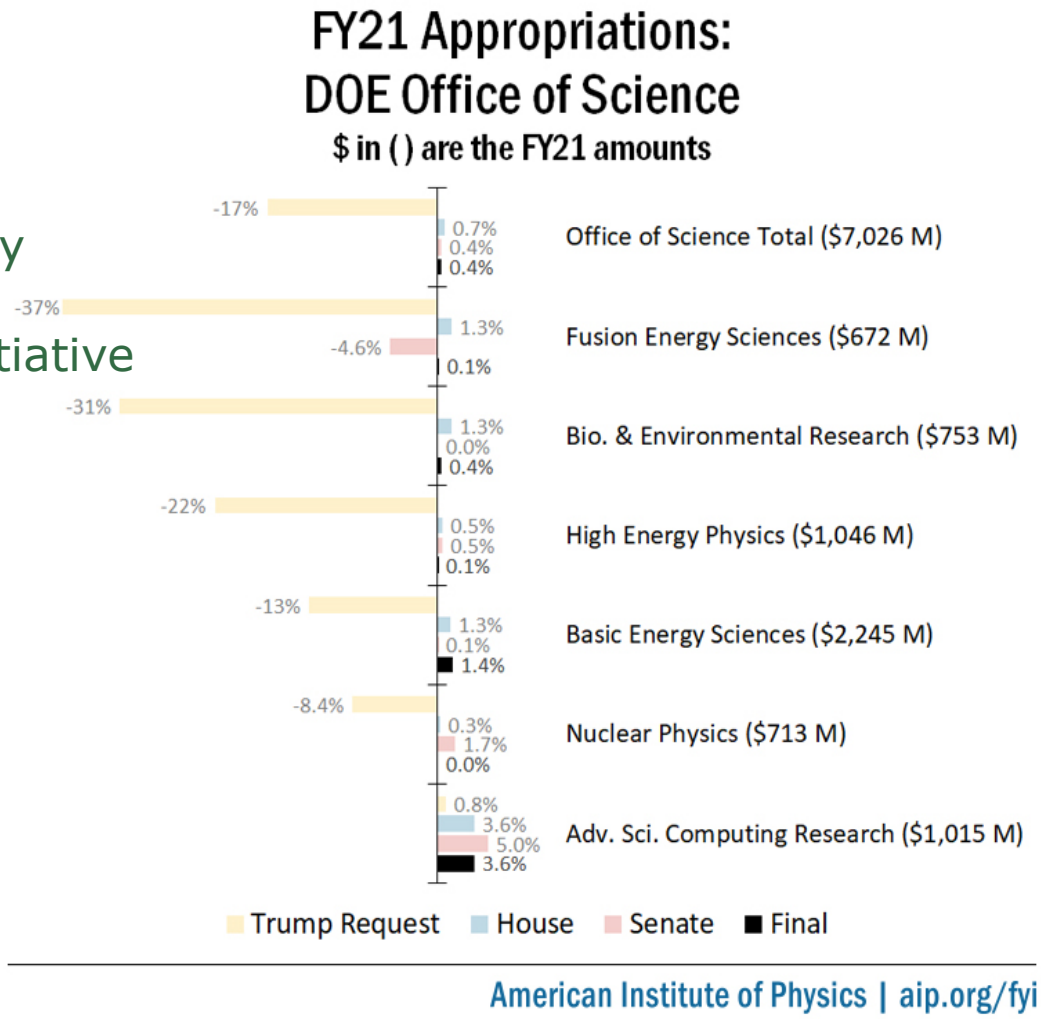
Review of FY 2021

- **DOE Office of Science (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**

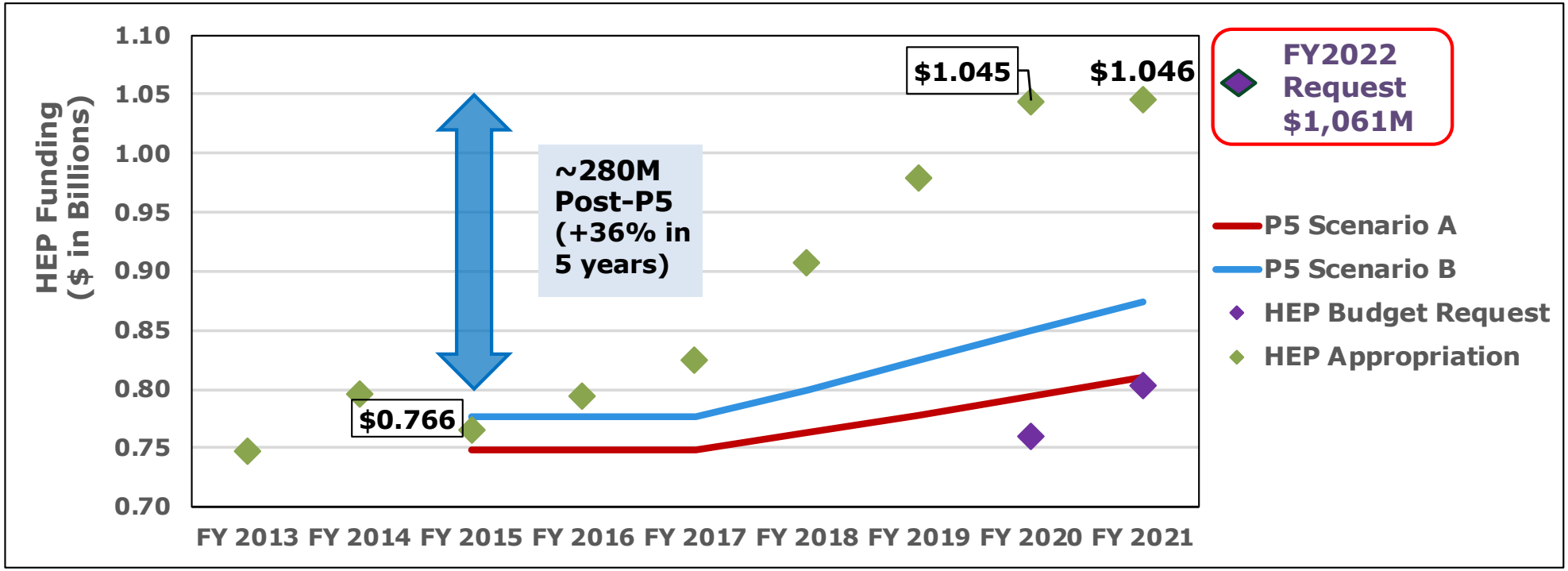
SC FY2021 Appropriation – details

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**

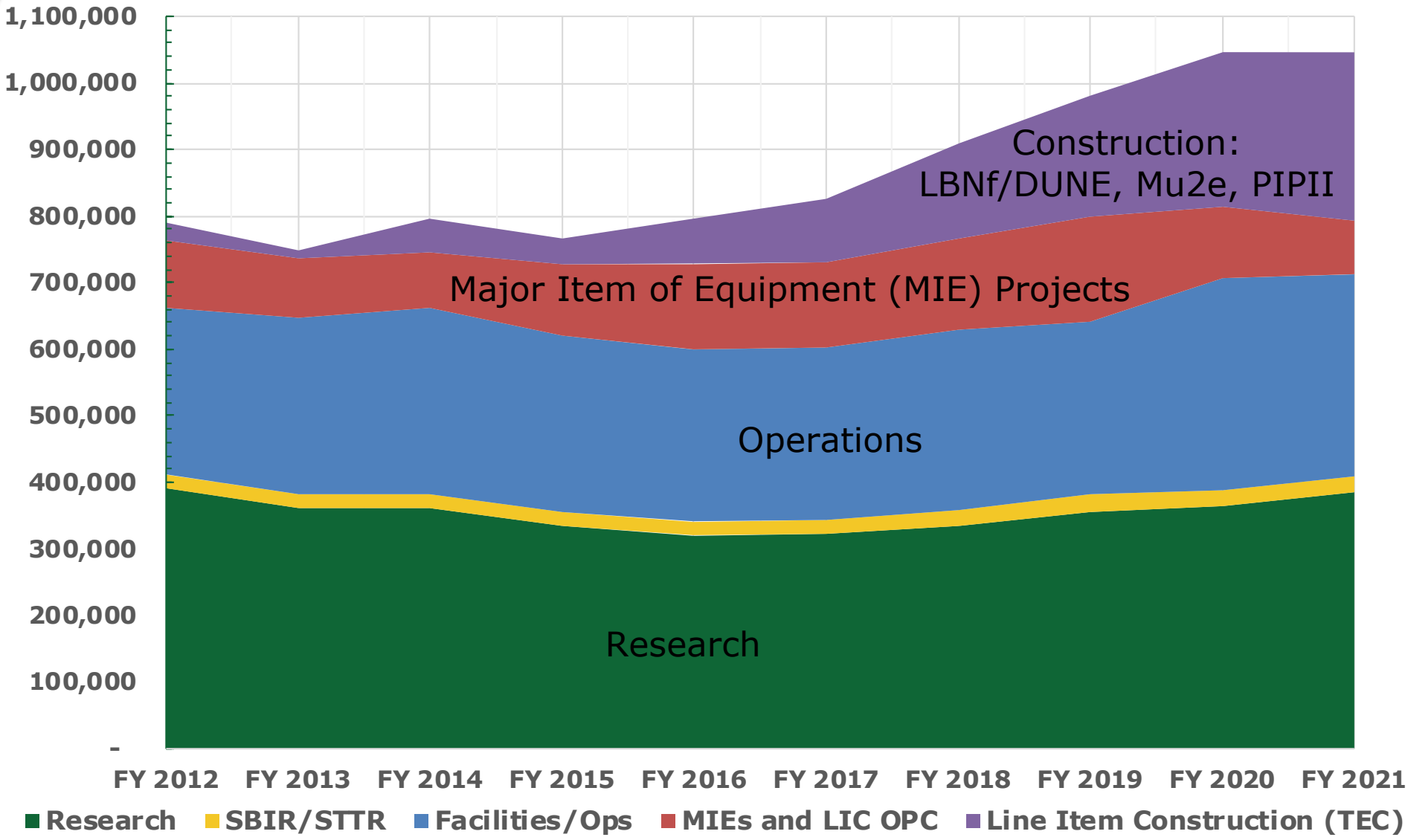


HEP Budget: U.S. Congress Supports P5 Strategy



- 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.

HEP Budget ($k) FY 2012-2021



FY 2022 Budget Request - HEP

HEP Funding Category (in $K)	FY 2019 Actual	FY 2020 Actual	FY2021 Request	FY 2021 Appropriation	FY2022 Request
Research	380,847	389,646	328,906	409,370	419,605
Facility & Exp. Operations	260,803	317,310	285,725	303,130	309,395
Projects	338,350	338,044	203,500	333,500	332,000
Total	**980,000**	**1,045,000**	**818,131**	**1,046,000**	**1,061,000**

FY 2022 President's Budget Request

- Continued strong support for continuing the HEP program and the P5 strategy.

New Initiatives in HEP

in $K	FY20 enacted	FY21 enacted	FY22 request
Accelerator Science & Technology		6,411	17,432
AI/ML	15,000	33,488	35,806
Integerated Computational & Data Infrastructure			4,146
Microelectronics		5,000	7,000
Quantum Information Science	38,500	45,072	51,566
Reaching a New Energy Sciences Workforce			4,000
TOTAL	**53,500**	**89,971**	**119,950**

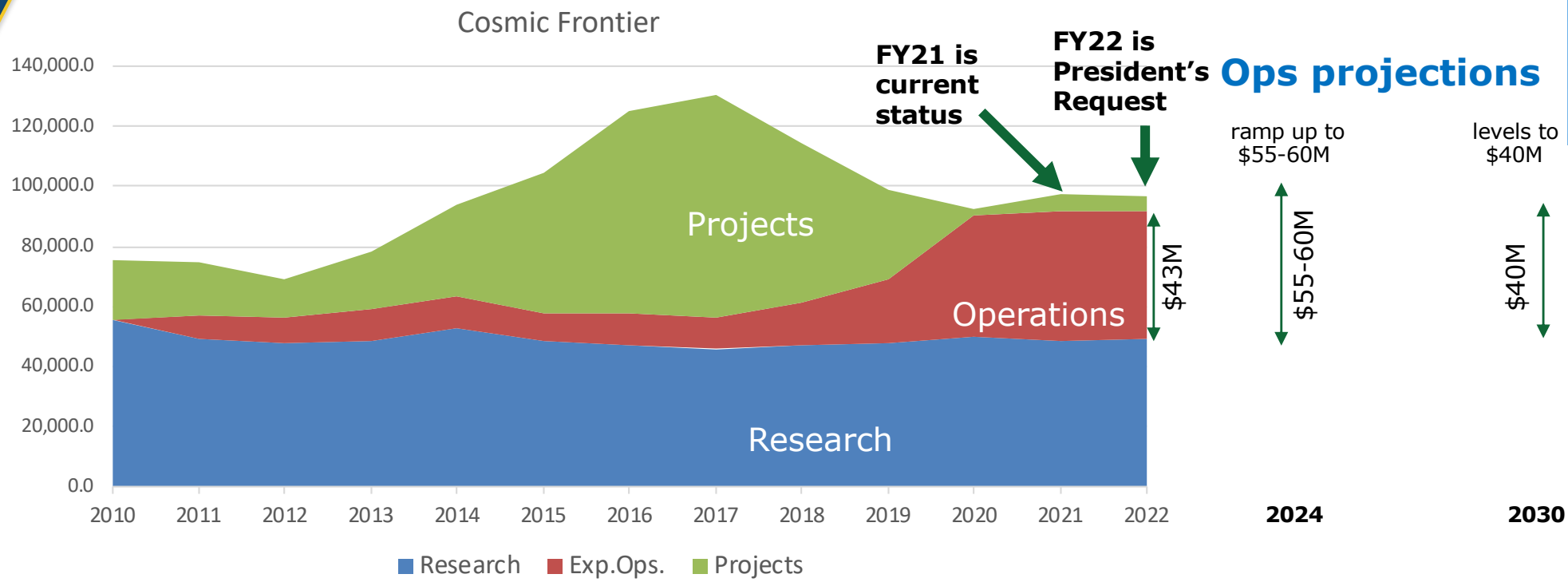
Reaching a New Energy Sciences Workforce → SC-wide RENEW initiative that leverages SC's unique national laboratories, user facilities, and other research infrastructures to provide undergraduate and graduate training opportunities for students and academic institutions not currently well represented in the U.S. S&T ecosystem. This includes Minority Serving Institutions and individuals from groups historically underrepresented in STEM, but also includes students from communities with environmental justice impacts and the EPSCoR jurisdictions. The hands-on experiences gained through the RENEW initiative will open new career avenues for the participants, forming a nucleus for a future pool of talented young scientists, engineers, and technicians with the critical skills and expertise needed for the full breadth of SC research activities, including DOE national laboratory staffing.

FY 2019-2022 Budget – Cosmic Frontier

Cosmic Frontier ($K)	FY2019 Actual	FY2020 Actual	FY2021 as of May	FY2022 Pres. Request
Research (Univ+Lab)	48,053	44,264	42,901	42,012
Research AI/ML		3,351	4,220	5,000
Future R&D	3,265	2,480	1,700	2,000
Exp. Operations	20,957	40,235	42,880	42,500
Projects	26,350	2,450	6,000	5,000
DESI	*9,350*	*0*	*0*	*0*
LZ	*14,450*	*0*	*0*	*0*
SuperCDMS	*2,550*	*0*	*0*	*0*
CMB-S4	-	*2,450*	*6,000*	*5,000*
Office support	3,667	4,181	4,436	
SBIR/STTR	2,869	3,524		
Total	**105,161**	**100,485**	**102,137**	**96,512**

- **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 continues.
- **Projects:** CMB-S4

Cosmic Frontier Budget History (FY12-21) + FY22 President's Request



Projections:

- Current projects begin to end by end of 2020s
- CMB-S4 just beginning, CD-0 2019
- Compelling Cosmic Frontier Projects will be considered and supported within available overall HEP Project funds. Guidance from Astro2020, next P5

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Cosmic Frontier

Cosmic Frontier
➔ Early Career Awards (Univ + Lab)

Cosmic Frontier - Early Career awards	FY16	FY17	FY18	FY19	FY20	FY21
#Proposals Received	**13**	**13**	**16**	**17**	**16**	**19**
Proposals Reviewed Univ	7	8	11	13	11	10
Proposals Reviewed Lab	6	5	5	4	5	9
Funded Univ	**1**	**1**	**2**	**3**	**3**	**3**
Funded Lab	**0**	**1**	**0**	**0**	**0**	**2**

Color code: **Dark Energy** **Dark Matter** **CMB**

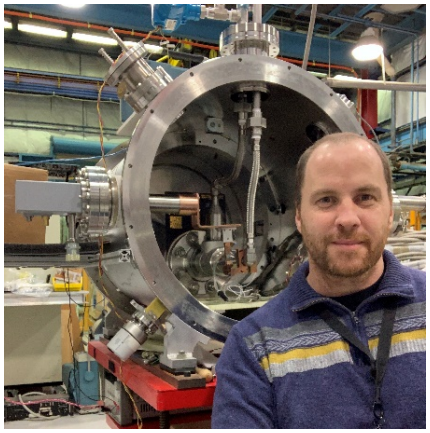
FY16	**Eduardo Rozo** **U. Arizona** 	**Anja von der Linden** **StonyBrook** 			
FY17	**Michael Schneider** **LLNL** 				
FY18	**Hee-Jong Seo** **Ohio U** 	**Alexie Leauthaud** **UCSC** 			
FY19	**Tim Eifler** **U. Arizona** 	**Elisabeth Krause** **U. Arizona** 	**Scott Hertel** **U. Mass** 		
FY20	**Hugh Lippincott** **UCSB** 	**Lado Samushia** **Kansas State** 	**Michael Troxel** **Duke** 		
FY21	**Lindsey Bleem** **ANL** 	**Chihway Chang** **U. Chicago** 	**Brian Nord** **Fermilab** 	**Dan Scolnic** **Duke** 	**Heidi Wu** **Boise State** 

Some Recent Awards

Juan Estrada (Fermilab)

APS DPF 2020 instrumentation award (Feb. 2021)

"for his creation and development of novel applications for charge-coupled device, or CCD, technology that probes wide-ranging areas of particle physics including cosmology, dark matter sensing, neutrino detection and quantum imaging."



Uros Seljak (LBNL)

2021 Gruber Cosmology Prize

with **Marc Kamionkowski** (Johns Hopkins University) & **Matias Zaldarriaga** (Institute for Advanced Study)

"for their work on the Cosmic Microwave Background, the most direct tracer of the primordial universe and of its physics. Their theoretical predictions and analysis tools for the cosmic background, its intensity, and even more its polarization, have been essential to the development of this field of research over the last 25 years, already testing predictions of the inflation model for the early expansion of our universe."

Dark Energy Survey (DES)

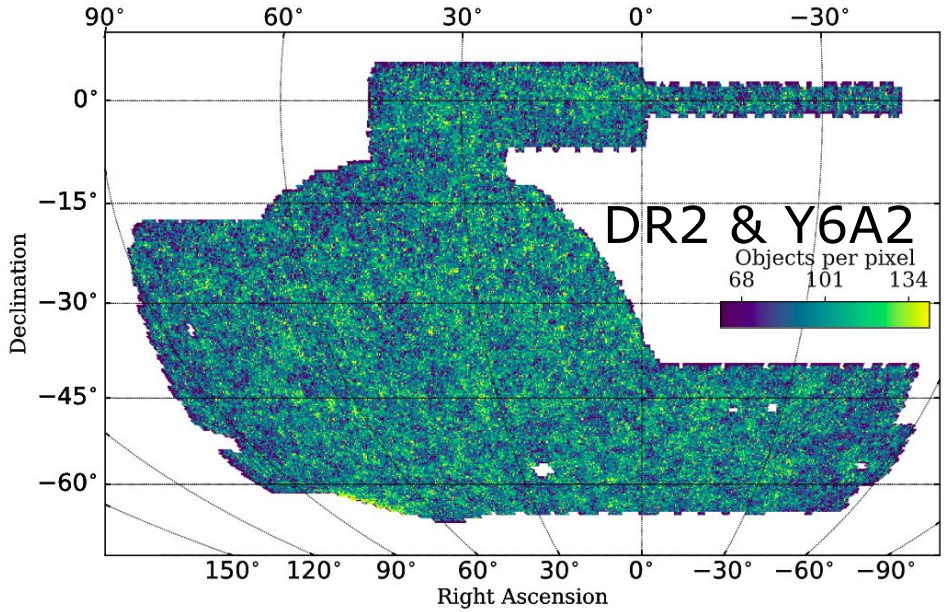
DARK ENERGY SURVEY

DOE and NSF partnership

- Fermilab led fabrication of 570Mpix Dark Energy Camera (DECam); NSF led telescope upgrades, data man. system
- Both agencies supported operations on NSF's Blanco telescope at CTIO in Chile.

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

- *Collaboration > 400 scientists from 25 institutions in 7 countries*
- Over 347 science publications with world-leading constraints on dark energy (including submitted)
- 91+ PhD's awarded (mid-May 2021)



Public Data Release 2, Jan. 2021:
6 years of single-epoch and co-added images, a source catalog, associated data products

Dark Energy Survey (DES)

May 27th: Press Release

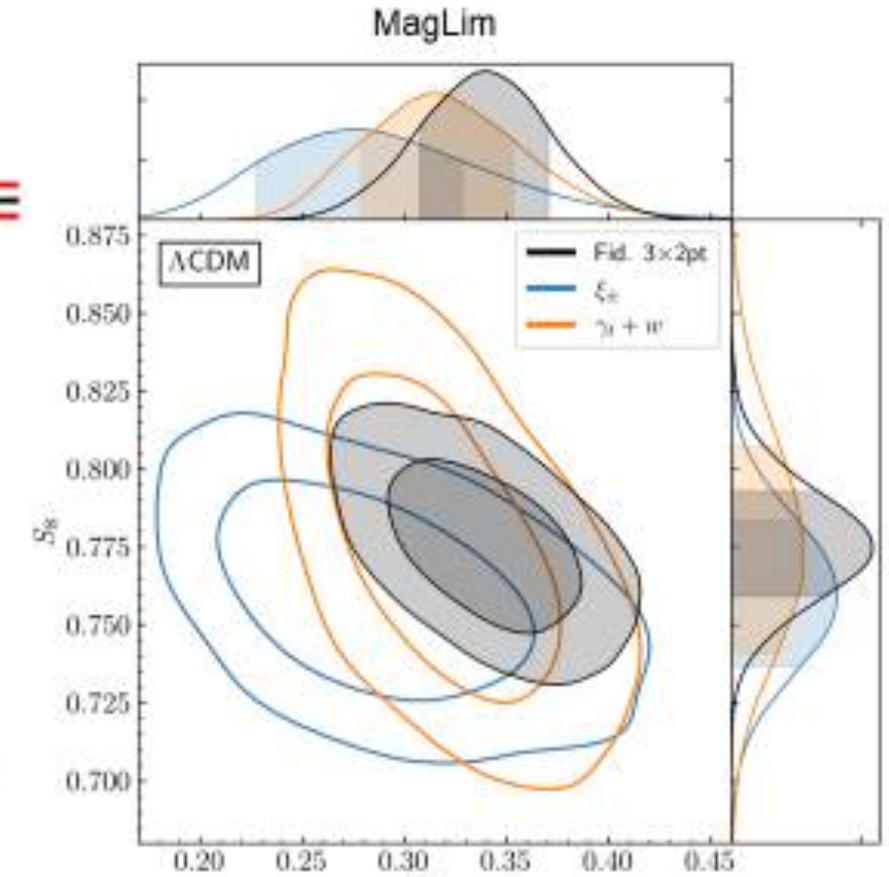
New results from DES using Y1-Y3 data -- the largest ever sample of galaxies (226 million) over an enormous piece of the sky to produce the most precise measurements of the universe's composition and growth to date.

DARK ENERGY SURVEY

Y3 Weak Lensing Cosmology Results

ΛCDM	$S_8 = 0.776^{+0.017}_{-0.017}$	(0.776)
	$\Omega_m = 0.339^{+0.032}_{-0.031}$	(0.372)
	$\sigma_8 = 0.733^{+0.039}_{-0.049}$	(0.696)
*w*CDM	$\Omega_m = 0.352^{+0.035}_{-0.041}$	(0.339)
	$w = -0.98^{+0.32}_{-0.20}$	(−1.03)

Data Analysis Results →consistent with predictions from the current best model of the universe. Nevertheless, hints remain from DES and other experiments that matter in the current universe is a few percent less clumpy than predicted.



https://news.fnal.gov/2021/05/dark-energy-survey-releases-most-precise-look-at-the-universes-evolution

Dark Energy Spectroscopic Instrument (DESI) Experiment

DOE/LBNL-led project:

- Instrumentation, Data Management System, & Upgrades of NSF's Kitt Peak Mayall telescope (including MOSAIC camera)
- Continues to lead Operations phase & science collaboration.
- Commissioning complete & was ready to take data in March 2020
  had to shut down due to covid-19
- Project CD-4 received May 2020
  re-commissioning, survey validation started Dec.2020

HEP has MOU w/NSF-AST to "lease" the Mayall telescope for operations phase

- Designed and built by large international collaboration
  - 500 researchers, 75 institutions, 13 countries, ~ 160 grad students.
- Partners
  - STFC, Heising-Simons, Gordon & Betty Moore, France, Mexico, Spain, NSF

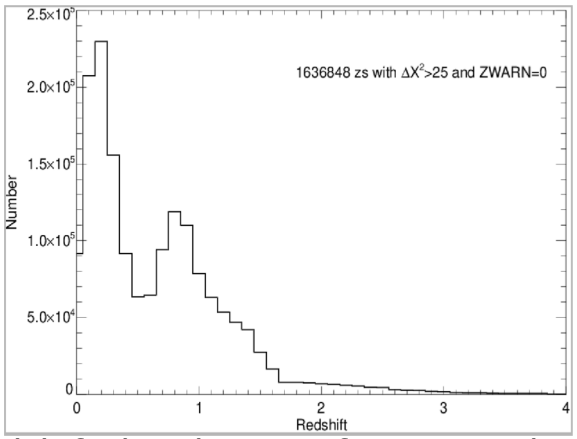
Thank you for strong support by NSF, NOIRLab and KPNO

DESI is now taking data!!!

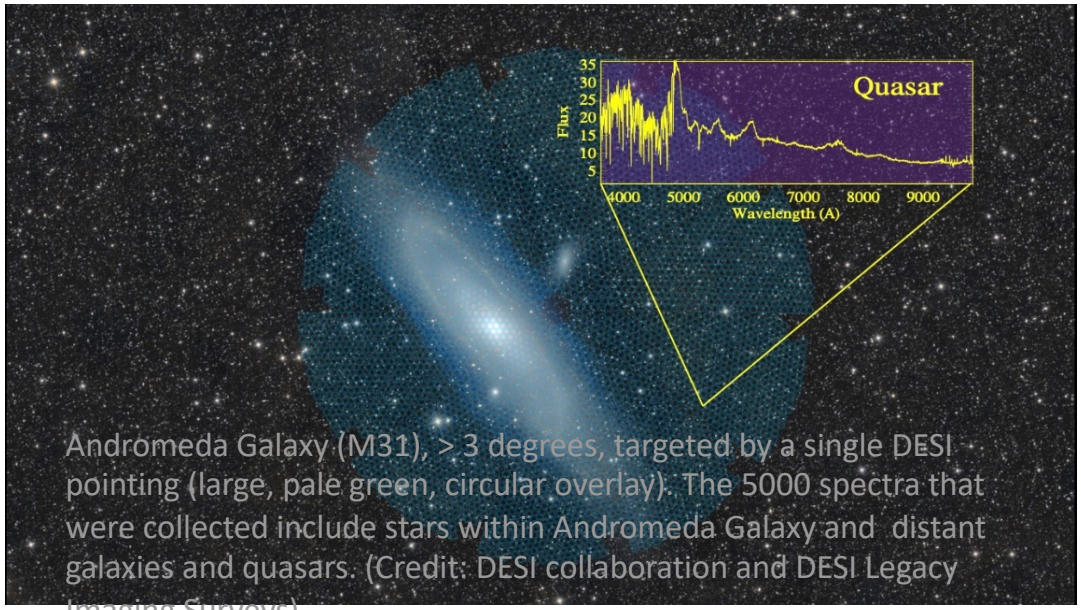
- **Science data-taking began May 14, 2021 !**
- World's premier multi-object spectrograph and the first **Stage IV dark energy** project to start **operations; will measure spectra of >40 million galaxies**

Jim Siegrist (HEP Director) → "We are excited to see the start of DESI, the first next-generation dark energy project to begin its science survey."

- LBNL led the 13-nation team, including U.S. government, private and international contributions, in the design, fabrication, and commissioning of the world's premier multi-object spectrograph. The strong interagency collaboration with NSF has enabled DOE to install and operate DESI on their Mayall telescope.



redshift distribution of unique galaxies studied to date



Andromeda Galaxy (M31), > 3 degrees, targeted by a single DESI pointing (large, pale green, circular overlay). The 5000 spectra that were collected include stars within Andromeda Galaxy and distant galaxies and quasars. (Credit: DESI collaboration and DESI Legacy Imaging Surveys)

LSST Camera Project & Commissioning

Project

Only remaining scope on the Camera Project is the filters.

- 5.5 filters are coated; the filters should be finished by the end of June. Metrology is going on in parallel. 3 filters have been mounted in the frame and a 4th is in progress.

r-band filter is coated and mounted in its frame; delivered to SLAC.

z-band and y-band filters have been mounted in their frames; are at LLNL ready to ship.

i-band filter has been accepted; at LLNL ready to be mounted to its frame.

g-band filter is fully coated and metrology underway.

u-band had its first surface coated.

Commissioning

- Camera sub-system assembly has made significant progress with completion of the cold metrology and the start of the electro-optical testing.
- Efforts are concentrating on refrigeration – ensuring stability and considering other systems as proactive mitigations if needed.

Vera C. Rubin Observatory

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

- **Project:** DOE responsible for the LSST Camera fabrication & commissioning (led by SLAC); NSF responsible for site infrastructure, telescope, data management system
- **Facility Operations:** 50/50 DOE & NSF split

LSST Camera status:

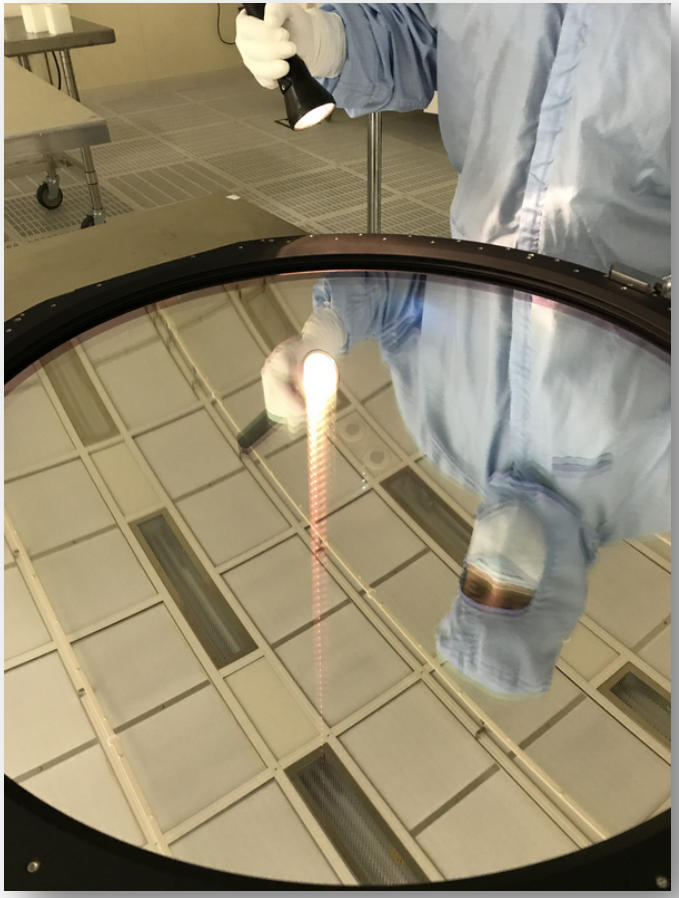
- Due to covid-19 delays, uncertainties, the project has been restructured to complete at the subsystem level (~ Aug. 2021)
- Full assembly and verification has been transferred to commissioning.
- Only remaining scope is filter completion
  - 11 of 12 surfaces are complete

HEP Commissioning roles (on Program funds)

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

Delay due to covid-19 of science survey start expected to be ~ 16 months.

LSST Camera Status



y-band during inspection at LLNL after completion of the mounting in the frame.

y-band filter in its inner container prior to final packing at LLNL.

Rubin Observatory: Facility Operations Planning

DOE & NSF will provide 50/50 support

DOE-supported efforts are primarily: Camera maintenance and operations & US Data Facility (USDF). SLAC was selected to be the managing organization for the USDF and will carry out all planned functions.

Planning status

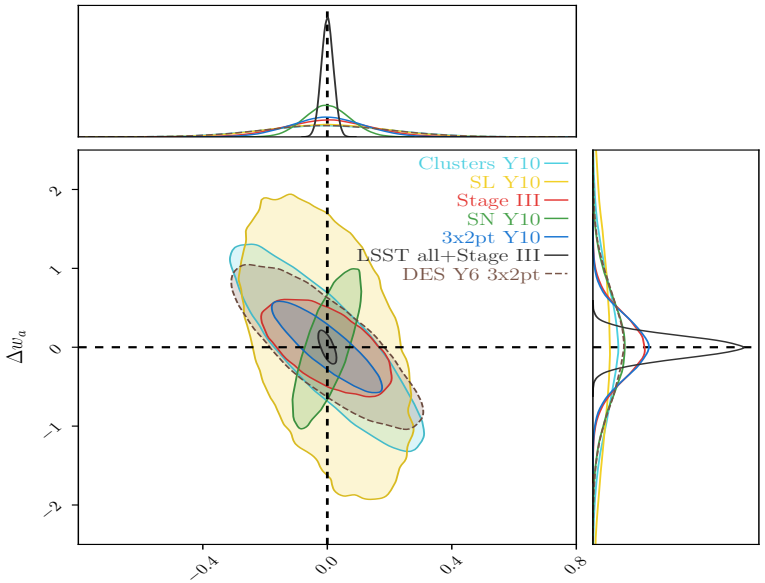
- Google interim data facility (IDF) up and running; SLAC USDF being developed and will ramp up in 2022/2023
- Operations team is selecting community members to participate in testing the system (IDF); will use DESC's simulated data. Selected users (a few hundred) will get access on June 30.
- International in-kind contributions (scientific partnerships) in exchange for data access during the proprietary period.
  - 33 proposals received with > 800 scientists (each PI can bring 4 junior people).
  - Community Evaluation Committee and Rubin Ops team assessing the proposals and will recommend to the agencies.
  - Next step will be to develop the agreements.
- Joint NSF-DOE review of the Operations plan will be held early 2022.

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

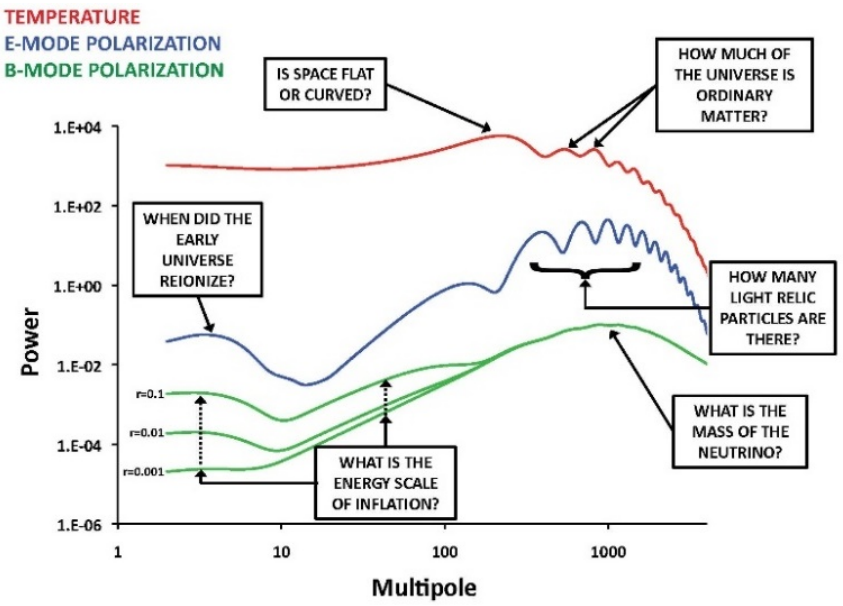
- Formalized an agreement for the Observatory to use DESC's Data Challenge 2 simulations in it's Data Preview 0 planning & effort.
- Contributing to observing strategy planning
- Possible opportunities to contribute to technical validation of Rubin Observatory during Commissioning.

See public release of DC2 at: https://lsstdesc-portal.nersc.gov/

Cosmic Microwave Background – Stage 4 (CMB-S4)

CMB-S4 recommended by P5 in all scenarios
- 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

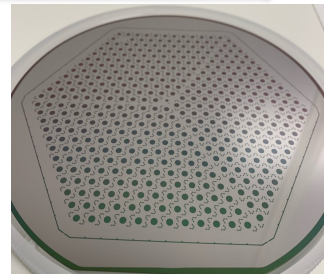
Collaboration has > 250 members!

- **Aug.2019** Project received Critical Decision 0 (CD-0)
- **Aug.2020**, LBNL chosen as DOE Lead lab; HEP status review
- **Dec.2020, FY21** budget appropriation provides $6M for R&D, project development
  - Congress approved it as a Major Item of Equipment (MIE) "project start"

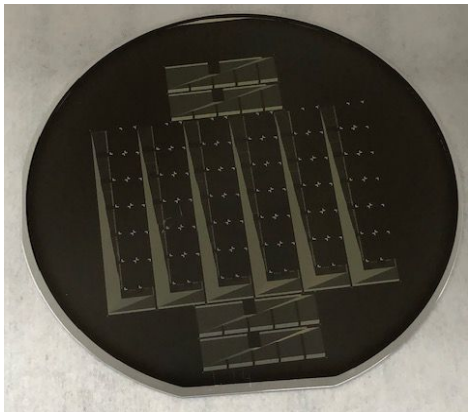
CMB-S4 Status & Plans

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

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

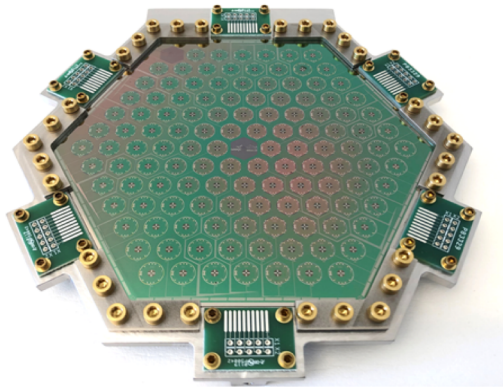


ANL wafer in process for FY21 R&D deliverables.



Prototypes of TES signal routing chips fabricated on 6" Si wafer at SLAC.

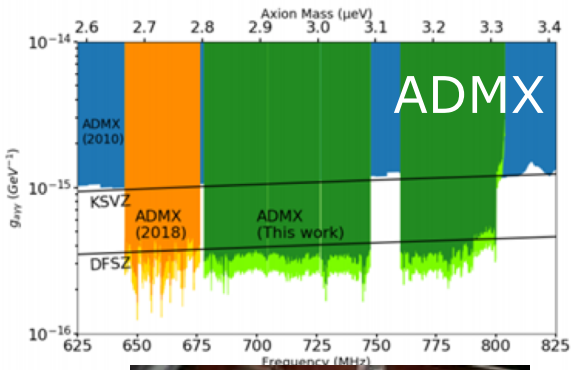
News:
- Series of 8 subsystem conceptual design reviews from late May through early August.
- Planning a status review led by DOE Office of Project Assessment status in early November.



Fabrication of a detector array holder by LBNL; it will be used to screen completed detector arrays for dark TES properties using DC SQUID readout systems.

Direct Detection of Dark Matter

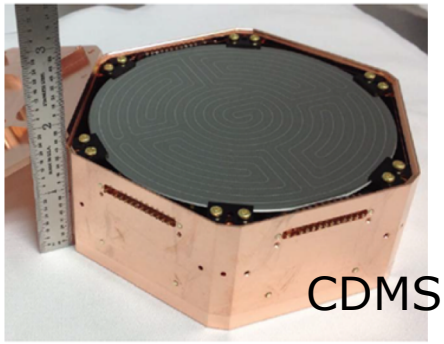
Staged suite of complementary direct detection experiments with multiple technologies to search for dark matter particles



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

ADMX-G2
- axion search (μeV-meV mass) operating at UWashington
- planned upgrades continue as they step through frequencies

LZ at Homestake Mine in South Dakota
- Dual phase liquid Xe WIMP search; ~10-1000 GeV mass
- Project fabrication complete; Commissioning is near completion, *expected by end of July; then LZ will start physics runs*



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 review in planned for end of Aug. 2021 planned
- Expect full fabrication completion in 2023; they can start operating with partial detector beforehand.

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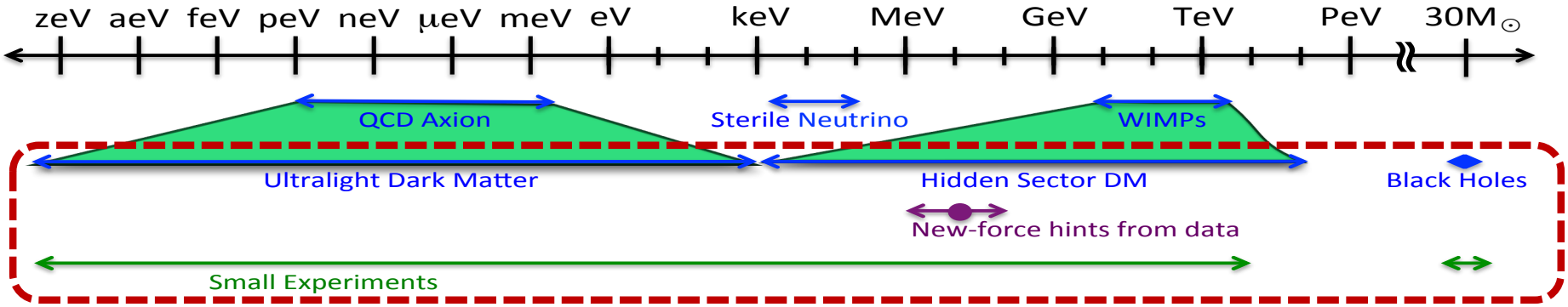
Future Planning

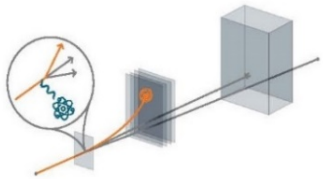
Dark Matter New Initiatives (DMNI) for small projects

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

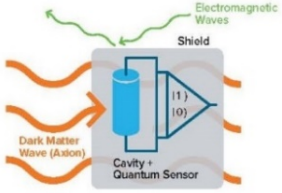


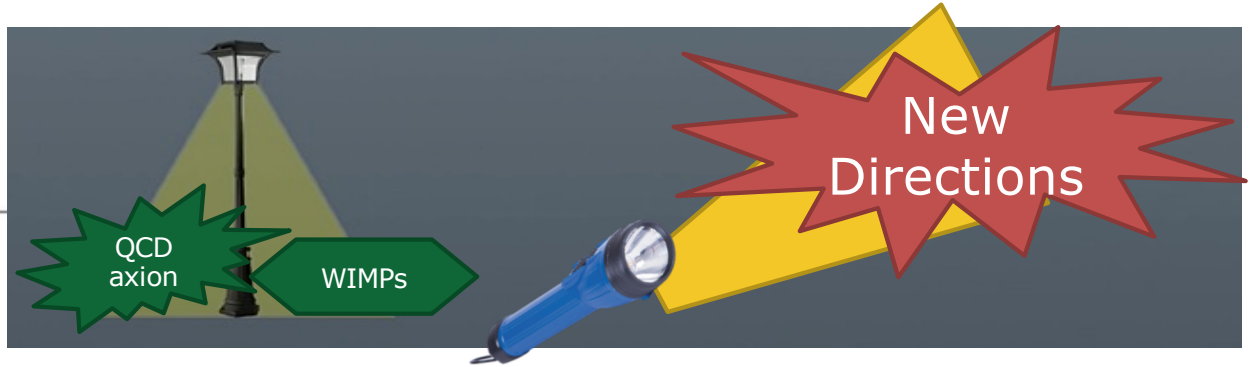
PRD 1
Create and Detect DM at Accelerators.



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**

→Since late 2019, HEP is supporting 6 concept teams to carry out near-term technology R&D and to develop design and execution plans that can be reviewed and considered for advancing to small project fabrication phase.

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)

Annual status review of the DMNI concepts now (June 1-4).

Joint DOE-NASA RFI - status

In Jan.2021, DOE Office of Science and NASA Science Mission Directorate jointly released a **Request for Information (RFI).** Responses were **due March 8th.**

- Goal: gather information from the community in 3 specific focused areas
  …aligned with the science goals of both of the program offices in partnerships that make use of both agency capabilities and infrastructure to enhance the science.

- DOE & NASA are currently reviewing the comments to inform and consider next steps in development of mutually beneficial partnerships or collaborative activities.

FYI: This RFI is part of a wider DOE/NASA effort to investigate collaborative activities:
See https://www.energy.gov/articles/department-energy-and-nasa-sign-memorandum-understanding

The 3 focused areas are:

1. Moon
   - 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
   - 11 papers received, mostly about 21cm cosmology

2. ISS
   - Small experiments to carry out space-based probes of fundamental physics in a microgravity environment of the International Space Station
   - 7 papers received, mixture of fundamental measurements (e.g. GR) and quantum science

3. Rubin+Roman+Euclid joint analysis (13 papers received)
   - Enhance or extend dark energy science data reach from the Rubin Observatory, Roman Space Telescope and the Euclid observatory when considered together
   - 13 papers received

Cosmic Frontier – Future Planning

Astronomy & Astrophysics "Astro2020" Decadal Survey

- Identify the most compelling science challenges and frontiers
- Develop a comprehensive strategy for 2022-2032.
- Results out soon, maybe July?

DOE & NSF charged the National Academy of Science to carry out an **Elementary Particle Physics (EPP) decadal survey**; starting ~ summer 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
  - Delayed 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.

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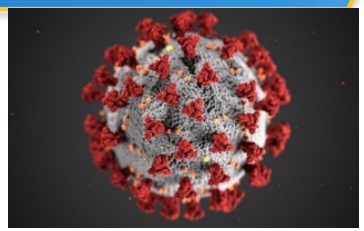
COVID-19 info & Summary

HEP COVID-19 Considerations & Plans



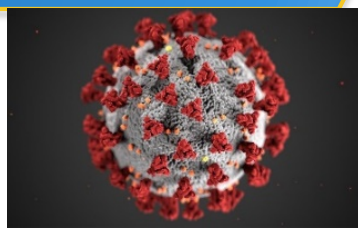
Operations:

- 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 ad hoc.

HEP COVID-19 Considerations & Plans



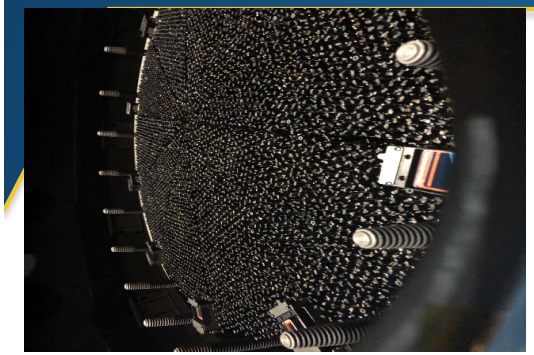
Research:

- HEP PI's have flexibility
  - They have significant flexibility within existing grant awards
  - Can re-plan their scope of work to accommodate research tasks that have been cut short or delayed by the pandemic
    - This includes extending support for junior scientists, which is one of our highest priorities
- We have been working with PIs on a case-by-case basis to address these issues as needed

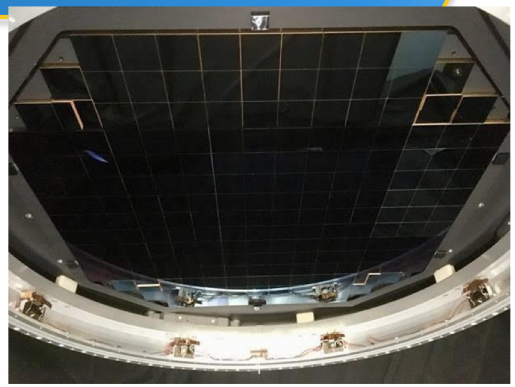
➔The need to continue support for existing students and postdocs may impact the availability of funds for new and renewal proposals.

Info at: https://www.energy.gov/science/downloads/doe-sc-accommodating-interruptions-applicants-awardees-due-covid-19

Summary

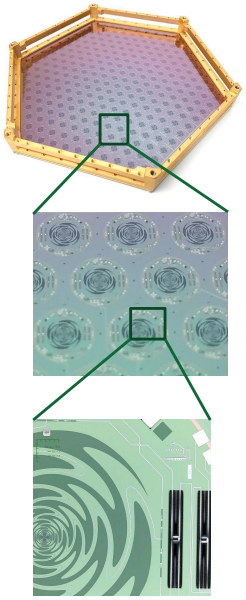


HEP continues to carry out the 2014 P5 strategic plan.
→ Many important interagency and international partnerships.



Cosmic Frontier:

- Continues to produce excellent, world-leading science results
- **DES Data Release 2 in January; Y3 results at end of May.**
- **DESI has started it science survey operations in mid-May**
- **LZ** (dark matter) in commissioning; data-taking this summer
- **LSST Camera** nearly complete, Commissioning ongoing
- **Rubin Observatory** Facility Ops planning is ramping up including **CMB-S4** – Approved as a fabrication project for DOE in the FY2021 budget; working towards planning for next decision points.
- **DOE/NASA RFI** to collect information on focused, potentially collaborative areas.
- **Future Planning** – Astro2020 and beyond



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