



U.S. DEPARTMENT OF
ENERGY

Office of
Science

Office of High Energy Physics (HEP) Cosmic Frontier

National Academies

Committee on Astronomy & Astrophysics

Nov. 8, 2021

Kathy Turner

Program Manager,

Experimental Research at the Cosmic Frontier

Office of High Energy Physics



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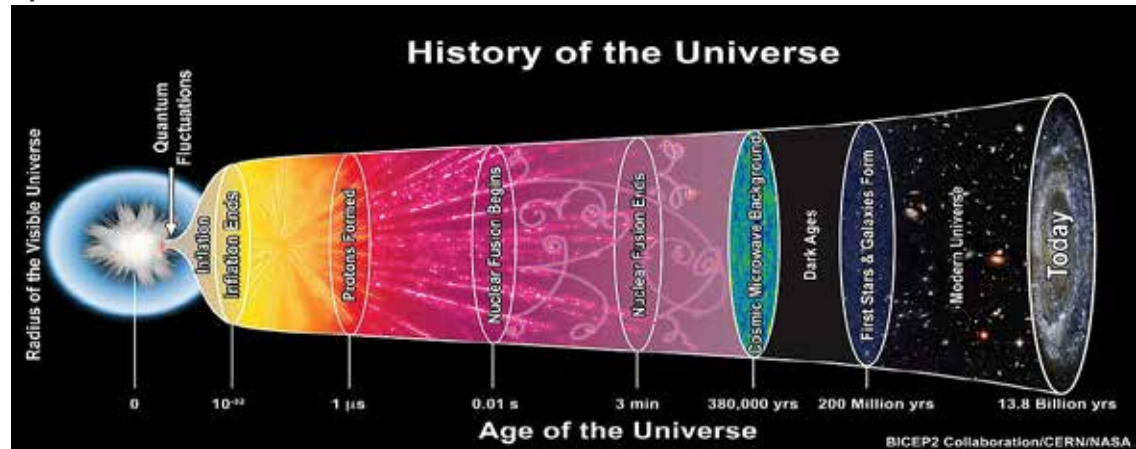
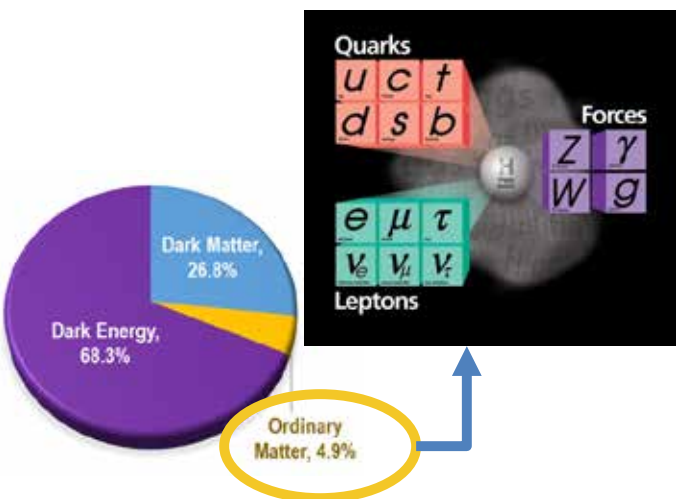
HEP Program

The Office of High Energy Physics (HEP) Program Mission

DOE is a mission-oriented agency à mission includes **maintaining a vibrant U.S. effort in science and engineering as a cornerstone of our economic prosperity with clear leadership in strategic areas.**

HEP's mission is to understand the universe at the most fundamental level:

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



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

DOE supports ~ 85 % of the U.S. HEP effort (in \$) at Universities + National Labs

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

à See Julie Carruthers talk at HEPAP, Nov. 2021

<https://science.osti.gov/hep/hepap/Meetings/202111>

} **Nov. 2020 report from SC's DEI working group à 15 Recommendations were developed that serve to ensure that SC's business processes:**

- § Are supportive & inclusive of women and underrepresented groups in STEM fields;
- § Allow for more rigorous tracking of diversity of applicants, awardees, reviewers;
- § Limit and mitigate potential implicit bias behaviors; and
- § Encourage inclusive and professional behaviors in all SC-sponsored activities.

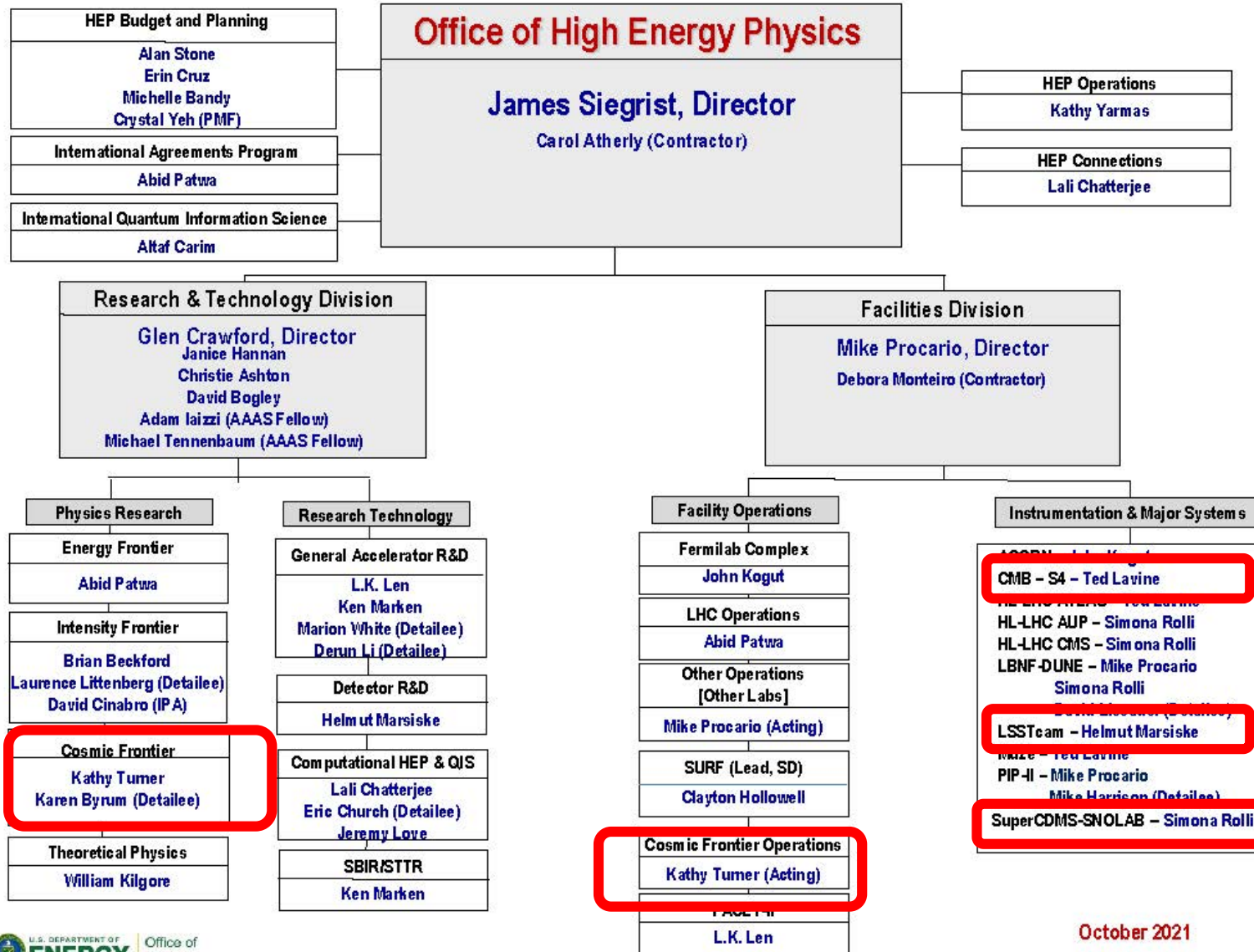
} **Dec. 2020 follow-on group is taking a phased approach, recognizing some actions will require longer development times than others.**

} SC-wide coordinated approach to increase SC participation by institutions and individuals historically underrepresented in SC-sponsored opportunities.

} **FY 2022 Request: Reaching a New Energy Sciences Workforce (RENEW)**

- RENEW initiative will support competitive undergraduate and graduate training opportunities for students and academic institutions not currently well represented in the U.S. S&T ecosystem to expand the pipeline for SC research and facilities workforce needs.

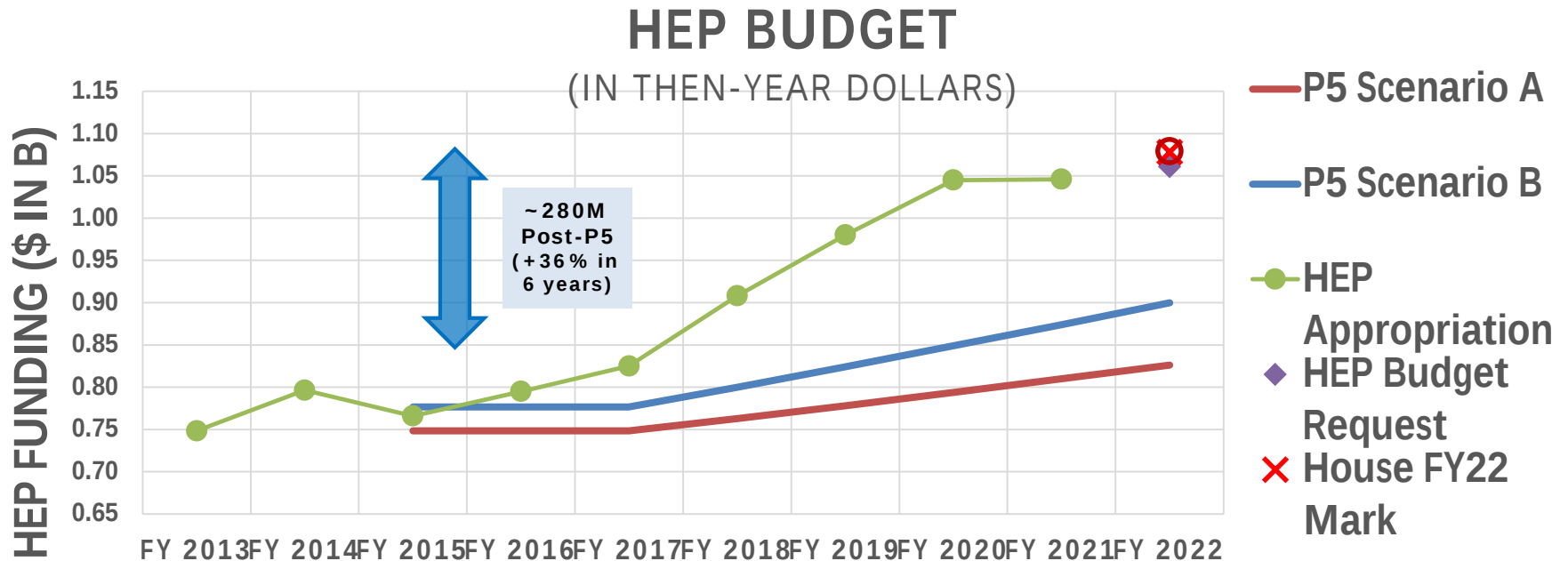
DOE Office of HEP



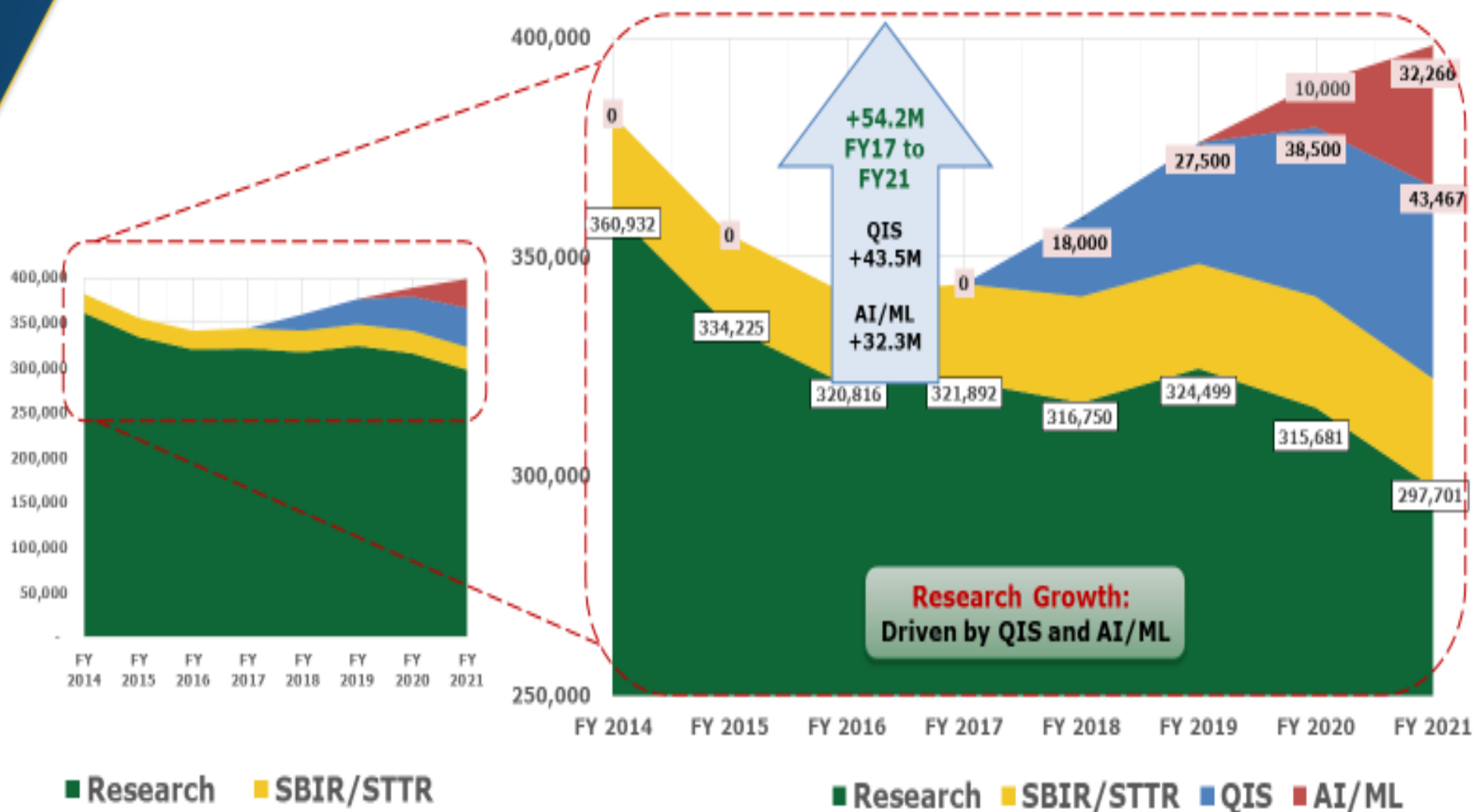
October 2021

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
- } When the P5 report was released in May 2014, the FY 2015 budget was already in Congress and the FY 2016 budget was being formulated
- } Arguably the first impact (success!) of the P5 report was not seen until FY 2016, and continues today...



HEP Research (\$k) FY 2014-2021



FY 2022 Budget Request - HEP

HEP Funding Category (\$ in K)	FY 2020 Actual	FY 2021 Request	FY 2021 Enacted	FY 2021 Actual	FY 2022 Request	FY 2022 vs. FY 2021
Research	389,646	328,906	398,203	408,163	419,605	21,402
Facilities/Operations	317,310	285,725	314,297	304,337	309,395	-4,902
Projects	338,044	203,500	333,500	333,500	332,000	-1,500
Total	1,045,000	818,131	1,046,000	1,046,000	1,061,000	15,000

FY 2022 President's Request is overlay of Administration, SC, P5 priorities

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

FY 2022 HEP Budget continues support for P5-guided investments

- } Research: Continue U.S. leadership in LHC, muon experiments, international neutrino experiments at Fermilab, **dark matter**, **dark energy**, and a vibrant theory program; QIS; AI/ML; Microelectronics (with ASCR, BES, and FES); Accelerator Science and Technology Initiative; Traineeships in accelerator science, instrumentation, high-performance scientific computing
- } Operations: Support HEP user facilities and running P5-recommended experiments
- } Projects and Line Item Construction: Project support for HL-LHC Accelerator and ATLAS & CMS Detectors, CMB-S4, and ACORN (new start); LIC support for LBNF/DUNE, PIP-II, mu2e

Note: FY 2021 Budget à

- } New Project Start for CMB-S4 Major Item of Equipment (MIE)

FY2022 Budget - Some Challenges

- } The FY 2022 President's Request Budget for DOE/HEP is down \$1.5 million for projects compared to the FY 2021 Appropriation
 - PIP-II accelerator project request is below the approved baseline
 - LBNF/DUNE is below the planned level
 - HL-LHC projects took larger cuts on a percentage basis
- } We remain committed to the P5 strategy and its priorities
 - Talking with international partners about our ongoing commitments and plans to successfully carry out HL-LHC and plans for LBNF/DUNE and PIP-II
 - Responding to questions from U.S. Congress on impacts
- } Congressional marks are slightly above the FY 2022 budget request for HEP, but final budget language will impact the allocation of any additional resources
 - HEP request: \$1.061B
 - House mark \$1.078B (+1.6%), Senate mark \$1.079B (+1.7%)

SC – [New] Initiatives

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

The President has placed a high priority on **American leadership in the Industries of the Future (IOTF):**

- artificial intelligence (AI), quantum information science (QIS), advanced manufacturing, biotechnology, and 5G/advanced wireless technologies



SC Initiative

- Artificial Intelligence & Machine Learning

As part of the AI initiative, FY21 SC appropriation included \$100M for AI

- SC has prioritized investments in AI/ML for user facilities focusing on accelerator optimization, control, prognostics, and data analysis

HEP FY2021 AI/ML funding contributed to:

- } Awards from dedicated FOAs (“Data, AI, and Machine Learning at DOE Scientific User Facilities”)
- } New Early Career Research Awards
- } Ongoing Laboratory research programs
- } New and renewal applications under standard HEP FOAs (including “HEP Comparative Review”)

HEP will continue to support dedicated new AI/ML efforts while enhancing support for existing AI/ML embedded in the ongoing research program.

FY22 Request: “Research to tackle the challenges of managing increasingly high volumes and complexity of HEP experimental and simulated data, and to address cross-cutting challenges across the HEP program in coordination with DOE investments in exascale computing and associated AI efforts.”

SC Initiative

- Advanced Microelectronics

“Thanks to microelectronics, transformational technologies that used to swallow up entire buildings now fit in the palms of our hands—and it’s time to take this work to the next level,” said **Secretary of Energy Jennifer M. Granholm**.

- “Microelectronics are the key to the technologies of tomorrow, and with DOE’s world-class scientists leading the charge, they can help bring our clean energy future to life and put America a step ahead of our economic competitors.”

FY21: 10 SC-wide multi-program awards (HEP is co-funding 2).

See: https://science.osti.gov/-/media/bes/pdf/Funding/2020/2491_Microelectronics_Awards.pdf

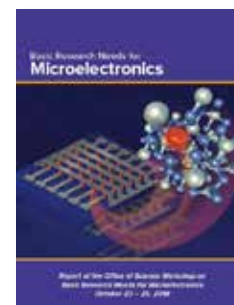
FY 2022 Request: ASCR, BES, FES, **HEP**, and NP will expand coordinated support for multi-disciplinary research to accelerate the advancement of microelectronic technologies.

Emphasis will be on basic research to advance

- New materials, chemistry, synthesis, and fabrication
- New computing paradigms and architectures
- Integrated sensing, edge computing, and communications
- Microelectronics resilience in high radiation or cryogenic environments

Microelectronics are:

- Critical for clean energy generation and efficient energy use
- Key to domestic manufacturing goals
- An opportunity to expand the research community at underserved institutions and communities



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SC Initiative

- QIS is a National and DOE Priority

“Quantum Information Science represents a foundational shift in our understanding of physics and information science, with the potential for dramatic technology impact.”

– Dr. Charles Tahan, Assistant Director for QIS, Office of Science and Technology Policy

QIS is an all-of-government effort, coordinated across agencies

- See <https://www.quantum.gov/>
 - } Quantum Sensing and Metrology
 - } Quantum Computing
 - } Quantum Networks and Communications
 - } Foundational Quantum Information Science Advances
 - } Supporting Technology
 - } Future Applications
 - } Risk Mitigation
 - } NQIA (National Quantum Initiative Act) Crosscut

SC core and Centers span most of the above

Major Milestones

- } 2018: National Quantum Initiative Act Passed by Congress
- } 2018: DOE Office of Science Quantum Initiative & Core programs
 - HEP competed the first round of QuantISED (Quantum Information Science Enabled Discovery) in FY 18 as part of the Office of Science QIS Initiative, with a second call in FY19.
- } 2020: National QIS Research Centers established by DOE. See <https://science.osti.gov/Initiatives/QIS/QIS-Centers>

HEP-QIS QuantISED research synthesizes

QIS for HEP & *HEP for QIS* in alignment with SC theme and connects to the HEP frontiers/thrusts

- } QuantISED supports interdisciplinary teams at DOE National Labs and at Universities
- } See: <https://science.osti.gov/hep/Research/Quantum-Information-Science-QIS>



SC Initiatives – New in FY2022

RENEW, Integrated Computational & Data Infrastructure

Reaching a New Energy Sciences Workforce (RENEW):

SC is fully committed to advancing a diverse, equitable, and inclusive research community. This commitment is key to providing the scientific and technical expertise for U.S. leadership. **HEP will participate in the SC-wide RENEW initiative which** 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.

- o 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.
- o 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.

Integrated Computational & Data Infrastructure for Scientific Discovery:

In coordination with SC, HEP will support development of data storage capabilities to handle tens of exabytes of data from future experiments; cross-cutting efforts in AI/ML and edge computing to seek solutions for real-time and extremely high data rate environments; and investments in software development to improve the interface with SC infrastructure and ASCR-supported middleware.



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Cosmic Frontier

Cosmic Frontier Experimental Research Program

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

Cosmic Acceleration:

- Study the nature of **Dark Energy** using imaging & spectroscopic surveys

- Use the **CMB** to study the Inflation

Dark Matter

- Direct Detection searches for **Dark Matter** particles using a variety of methods and technologies

Neutrinos

- Constrain properties using dark energy & CMB measurements

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

Always interested in Exploring the Unknown and New Physics!

Cosmic Frontier – Program Planning

- **Astro2010 recommended DOE/NSF partnership on LSST (Rubin)**
- **P5 (2014) recommended Cosmic Frontier science & project priorities in Dark Energy, Dark Matter (direct detection) & CMB**
 - **Dark Energy:** build LSST (Rubin) & DESI
 - **Dark Matter:** suite of “generation 2” direct detection experiments
 - **CMB:** support as part of the core program within multi-agency context; carry out multi-agency CMB-S4 project later in the decade
 - Maintain a portfolio of **small projects**: e.g. we are carrying out ADMX-G2, SPT-3G, Dark Matter New Initiatives

Notes:

- Most Experiments are done in partnership with NSF-PHY, NSF-AST, NSF-OPP, NASA, and/or International agencies/institutions.
- Significant contributions & support from other HEP areas, e.g. Theory, Advanced Detector Development, Computational HEP, QIS, AI/ML
- Contributions from other SC areas à ASCR Supercomputing resources

Astro2020 Recommendations for DOE/HEP

Astro2020 recommended DOE/NSF partnership on CMB-S4 and made recommendations regarding demographics, data etc.

Recommendation: NSF & DOE should jointly pursue the design & implementation of the next generation ground-based cosmic microwave background experiment (CMB-S4).

"An important requirement for our strong endorsement is that the project broadly engage astronomers beyond the traditional CMB community. CMB-S4 will produce data sets of unprecedented sensitivity, cadence and spectral coverage that will advance general astrophysics and open discovery space opportunities for diverse scientific communities. Previous CMB experiments have not had the charge or funding to make data rapidly available and generally usable. It is essential that CMB-S4 produce transient alerts, as well as calibrated maps in all bands and on all angular scales that are openly usable and accessible on as rapid a cadence as practical."

FY 2019-2022 Budget – Cosmic Frontier

Cosmic Frontier (\$K)	FY2019 Actual	FY2020 Actual	FY2021 Approp.	FY2021 Actual	FY2022 Pres. Req.
Research (Univ+Lab)	48,053	44,264	39,634	43,901	42,012
Research AI/ML		3,351	3,920	4,920	5,106
Future R&D	3,265	2,480	2,000	1,700	2,000
Exp. Operations	20,957	40,235	43,897	42,880	42,500
Projects	26,350	2,450	6,000	6,000	5,000
<i>DESI</i>	9,350	0	0	0	0
<i>LZ</i>	14,450	0	0	0	0
<i>SuperCDMS</i>	2,550	0	0	0	0
<i>CMB-S4</i>	-	2,450	6,000	6,000	5,000
Total	98,625	92,780	95,451	99,401	96,618
Office support	3,667	4,181	4,436	4,970	*
SBIR/STTR	2,869	3,524		1,624	*
Total Full	105,161	100,485	99,887	105,995	

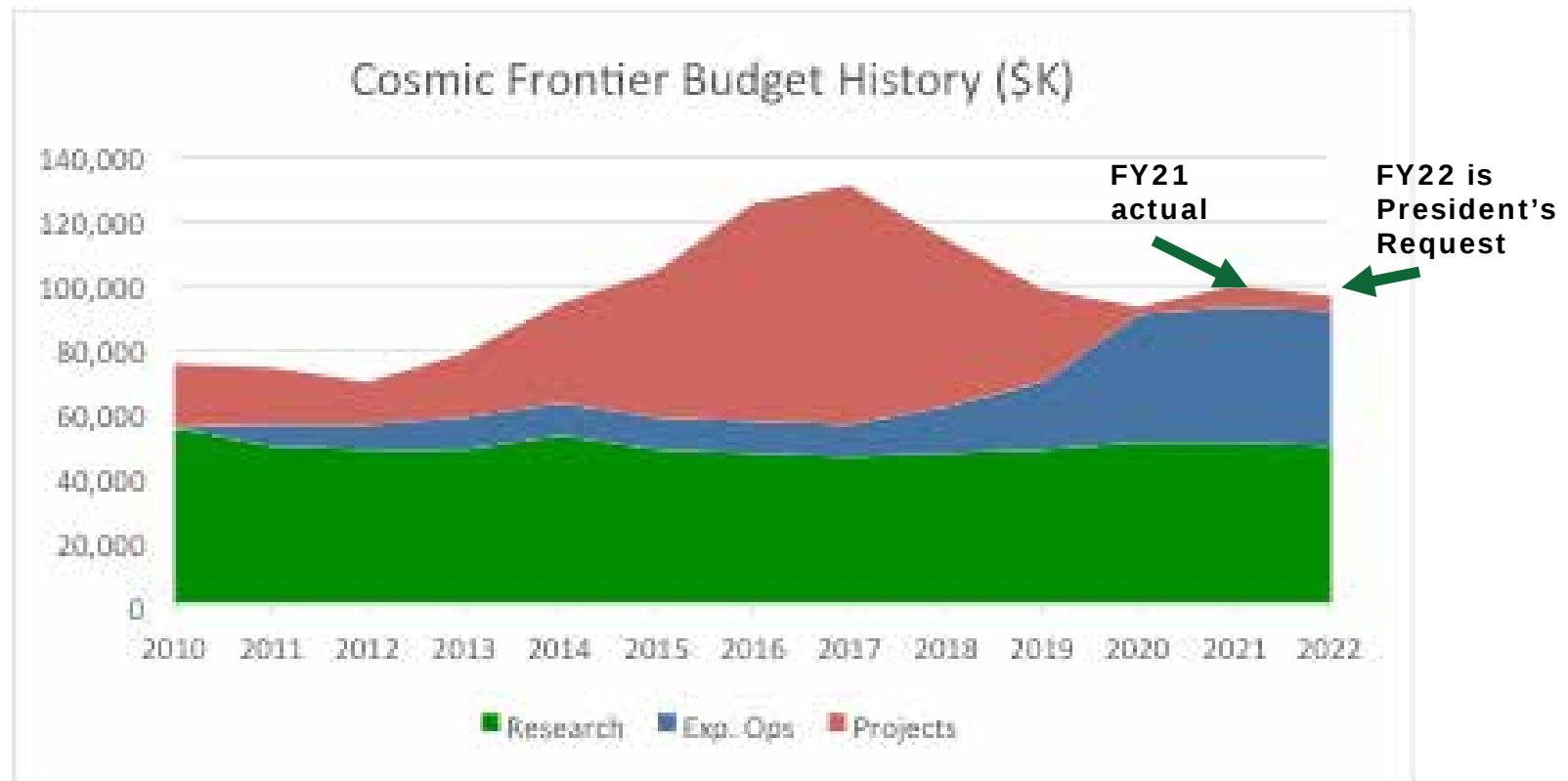
} **Research:** Scientist support for world-leading efforts in design and optimization in their planning, fabrication, commissioning, operations and data production/analysis.

} **Operations:** Commissioning and facility operations planning for LSST/Rubin; operations of FGST/LAT, SPT-3G, ADMX-G2, DESI, LZ; pre-operations activities for SuperCDMS-SNOLAB.

} **Projects:** CMB-S4

* These costs have not yet been applied for FY22

Cosmic Frontier Budget History



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

Dark Energy Survey (DES)



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

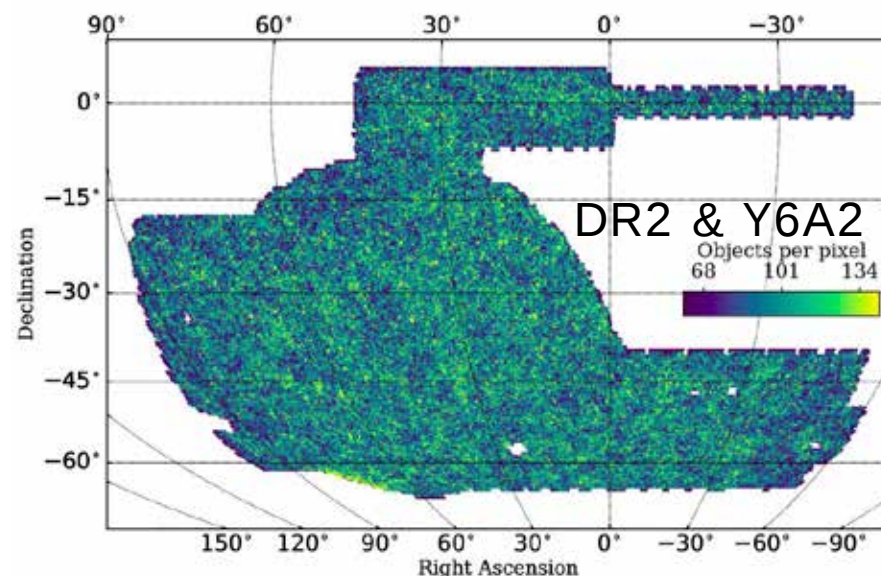


- *Collaboration > 400 scientists from 25 institutions in 7 countries*
- Over 370 publications; > 90 PhD's

Cosmology 7 ways:

Growth rate of structure and Expansion History: Weak Gravitational Lensing, Galaxy Clustering, & Galaxy Cluster Abundance

Expansion History: BAO (standard rulers), SNIa (standard candles), Gravitational Wave Follow up (standard sirens), Strongly-Lensed Transients.





Dark Energy Survey (DES)

– Science Highlights



Jan. 2021: Public Data Release 2 (Y1-Y6 data). 690M objects with unprecedented photometric, astro-metric precision & uniformity.

Jan. 2022 (at AAS) Y3A2 “Gold” public release

$$\Lambda\text{CDM}$$

$$\sigma_8 = 0.812^{+0.008}_{-0.008} \quad (0.815)$$

$$\Omega_m = 0.306^{+0.004}_{-0.005} \quad (0.306)$$

$$\sigma_8 = 0.804^{+0.008}_{-0.008} \quad (0.807)$$

$$h = 0.680^{+0.004}_{-0.003} \quad (0.681)$$

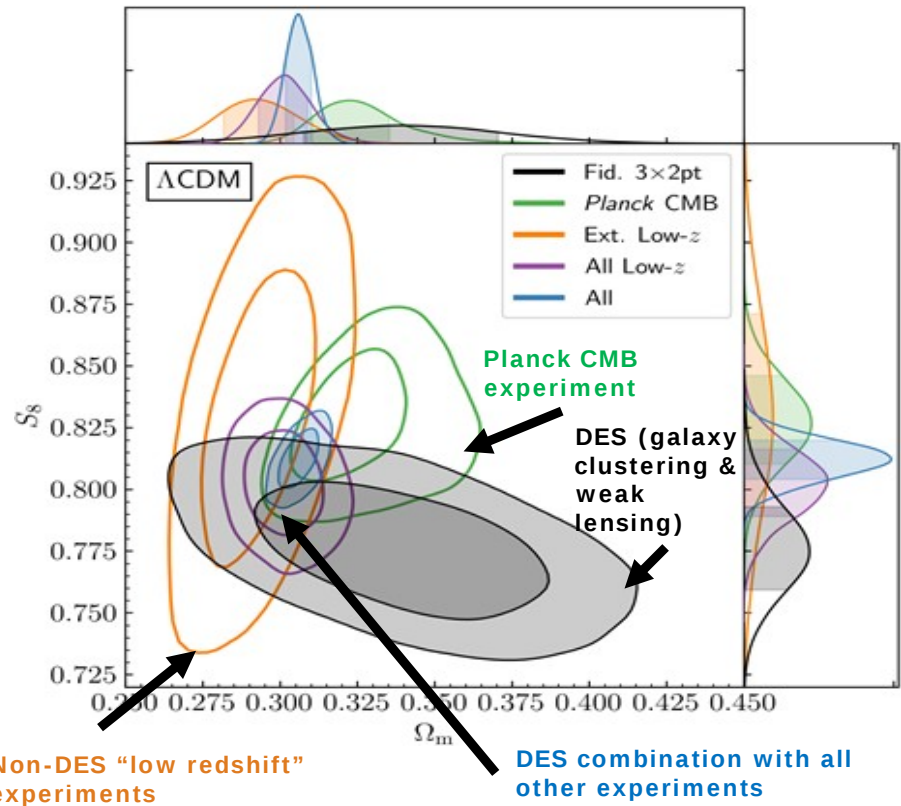
$$\sum m_\nu < 0.13 \text{ eV (95\% CL)}$$

$$w\text{CDM}$$

$$\sigma_8 = 0.810^{+0.010}_{-0.009} \quad (0.804)$$

$$\Omega_m = 0.302^{+0.006}_{-0.006} \quad (0.298)$$

$$w = -1.03^{+0.03}_{-0.03} \quad (-1.00)$$



Y3 Weak Lensing Cosmology Results from Y1-Y3 data → the largest ever sample of galaxies (used 100 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 (DES) – Science Highlights

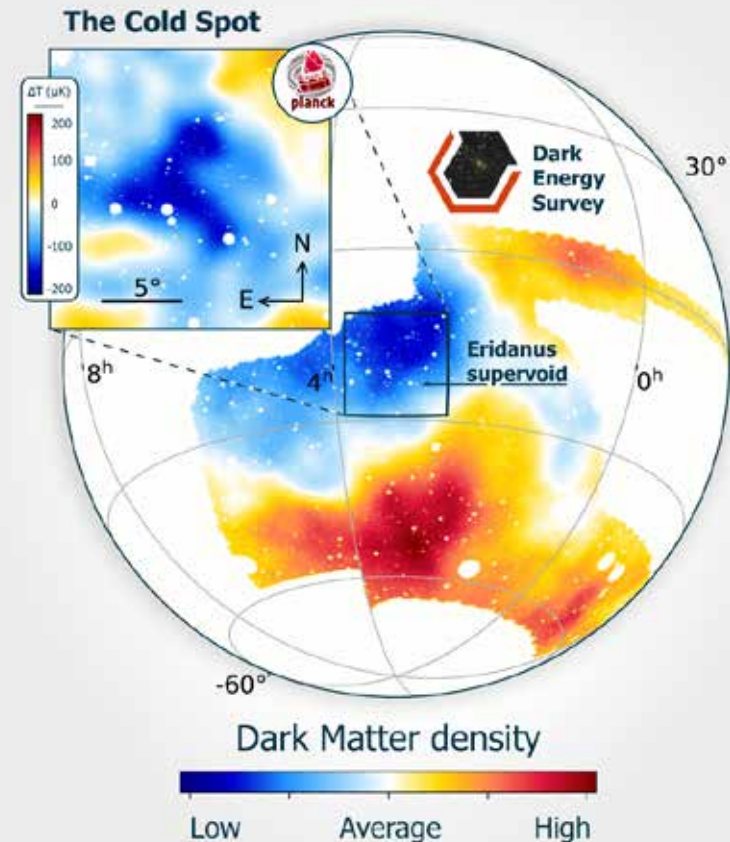


Growth of Structure – from cosmic voids:

- Association of a foreground "supervoid" is evident in the DES weak-lensing mass map with the so-called Cold Spot in the CMB.
- The Cold Spot may be due to, or enhanced by, a net redshift as the CMB photons pass through a region of low mass on their way to us.
- Helps to understand how structure has evolved from the CMB to the present. This study is about what is happening between the clusters.

Primary authors: A. Kovács*, N. Jeffrey, M. Gatti, C. Chang, L. Whiteway, N. Hamaus, O. Lahav, G. Pollina et al.
(*corresponding author, akovacs@iac.es)

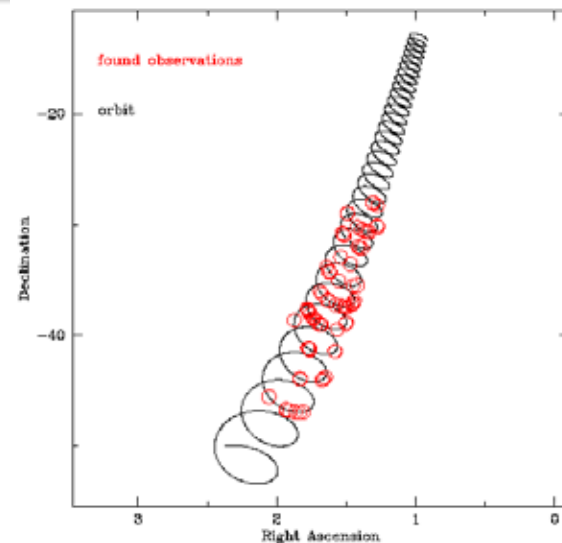
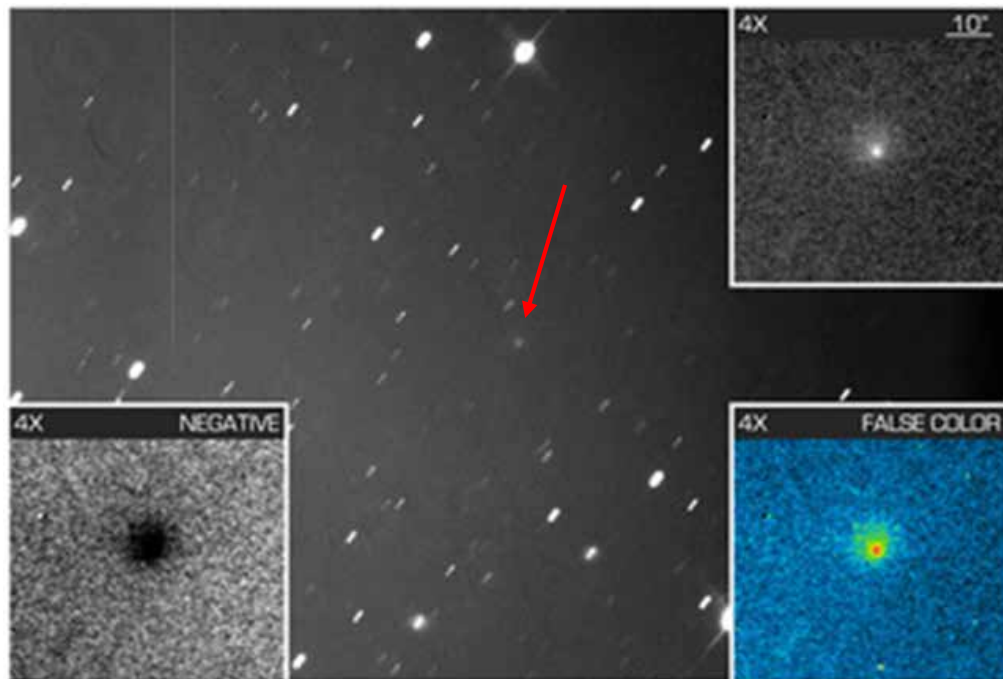
Preliminary



The Cold Spot resides in the constellation Eridanus in the southern galactic hemisphere. The inset shows the microwave temperature map of this patch of the sky as mapped by the Planck satellite. The main figure depicts the dark matter mass map created by the DES team. Graphics by Gergő Kránicz and András Kovács.

DES – other exciting science topics è Discovery of New Comet!

- Ø A new comet, the most massive and most distant ever discovered, found using DES data
- Ø C/2014 UN271 “Bernardinelli-Bernstein”



- Ø Comet C/2014 UN271 was detected as it came in from the Oort cloud at 29 to 23 AU
- Ø Massive (~200 km wide) comet
- Ø Early studies of the coma show sub-mm sized grains at 7 m/s as well as sublimation of CO
- Ø Perihelion at 11 AU in 2031, so we'll watch this one “turn on” for a long time

Dark Energy Spectroscopic Instrument (DESI) Experiment

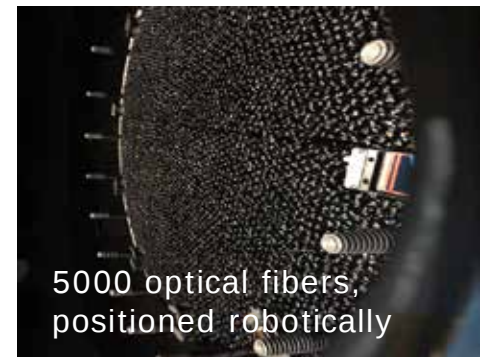


DOE's DESI is taking data!

- World's premier multi-object spectrograph and the first **Stage IV dark energy** project started full science operations May 2021
- Achieved design plans in performance and survey depth/parameters.
- Will measure spectra of > 40 million galaxies

DOE/LBNL-led project:

- **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 & ready to take data in March 2020; then had to shut down due to covid-19
- Project CD-4 received May 2020; re-commissioning, survey validation started Dec.2020



5000 optical fibers,
positioned robotically



- Designed and built by large international collaboration
 - 500 researchers, 75 institutions, 13 countries, ~ 240 grad students
- Partners
 - STFC, Heising-Simons, Gordon & Betty Moore, France, Mexico, Spain, NSF
 - HEP has MOU w/NSF-AST to "lease" the Mayall telescope for operations

DESI Instrumentation

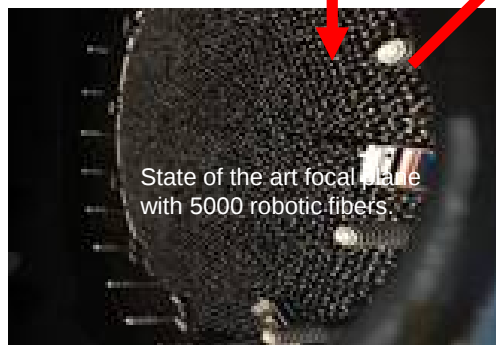


DESI's state of the art instrumentation covers an 8 square degree field of view, about 38 times larger than that of the full moon, including:

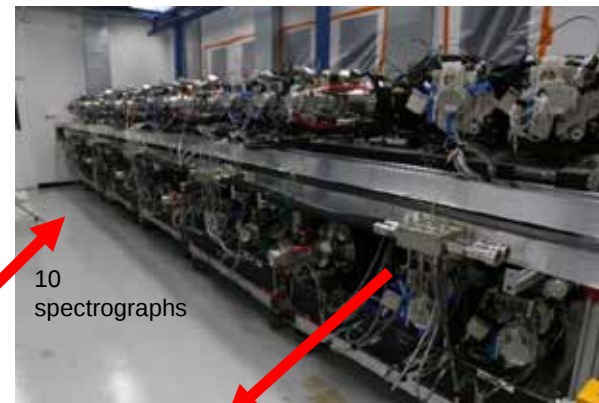
- 6 exquisitely polished corrector lenses
- 5000 fiber-fed robotic positioners – focal plane
- 10 spectrographs, each with 3 wavelength ranges of blue (360 to 593 nanometers), red (566 to 772 nm) and infrared (747 to 980 nm)



500,000 lbs. of moving weight



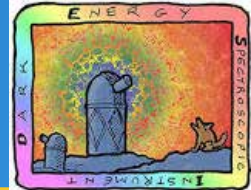
State of the art focal plane with 5000 robotic fibers



10 spectrographs

To data processing at NERSC supercomputing center.

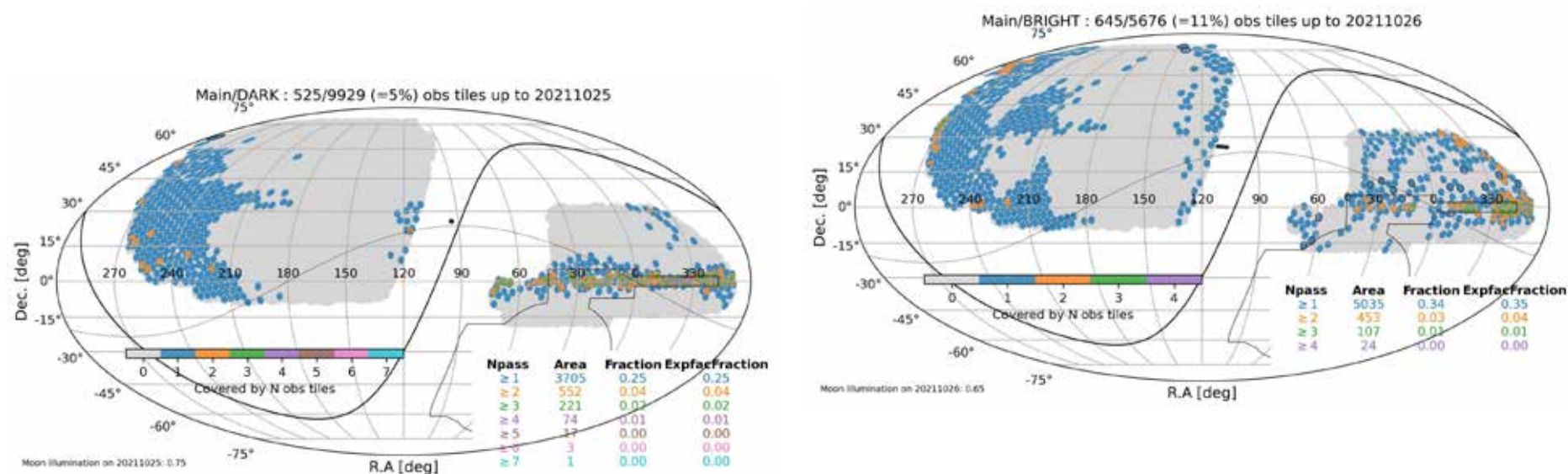
DESI – survey status



After summer shutdown, Observing Operations are back to full steam in October

- more than 4 million galaxy + quasar redshifts recorded since the start of the main survey on May 14, 2021
- on October 8, DESI broke its own record for the most redshifts recorded, 103,179 galaxies and quasars in a single night.

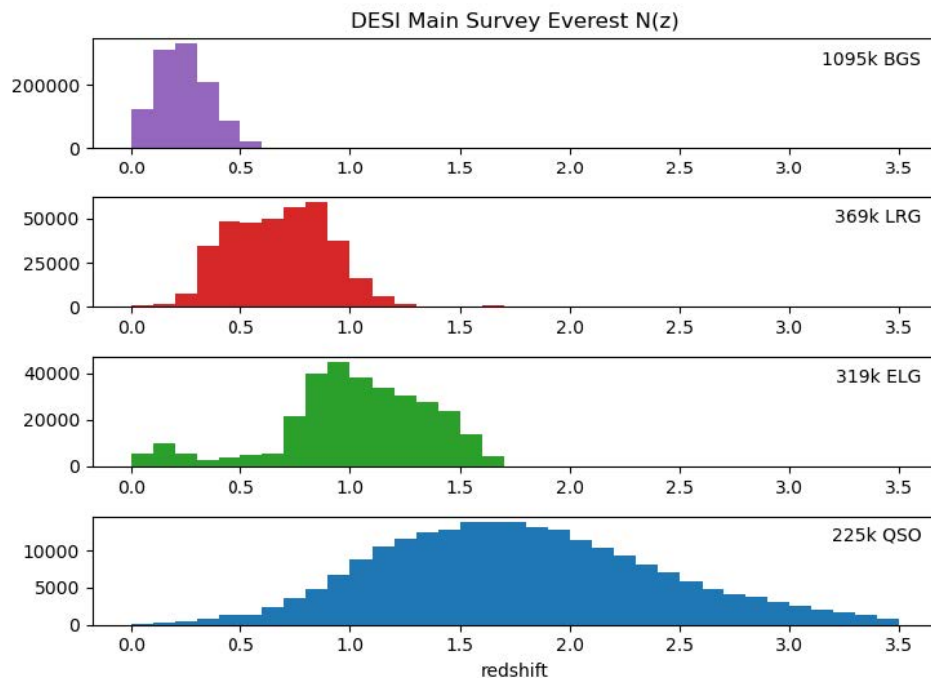
DOE 2020 Project Management Excellence Award presented to DESI Oct. 25 by Under Secretary Kathleen Hogan.



DESI – survey status



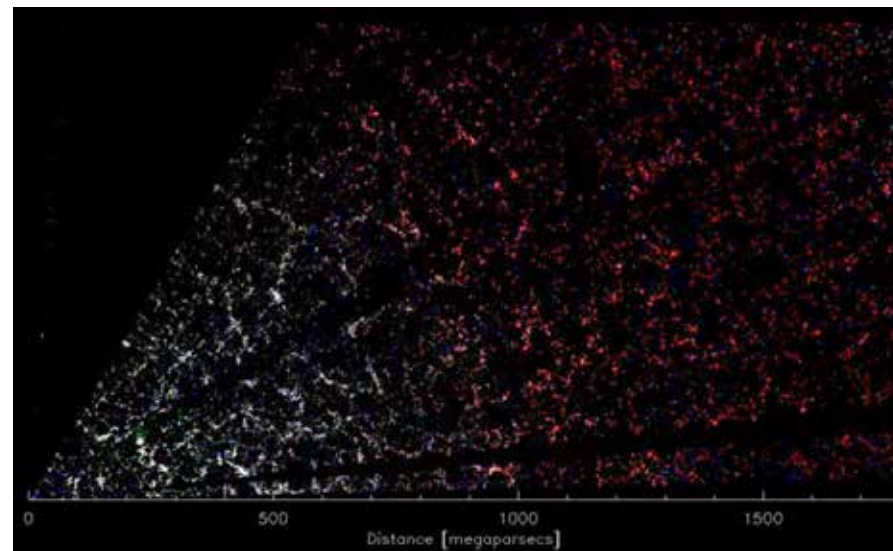
Redshift distribution of 2M spectra taken by DESI in each target class (Sept 2021)



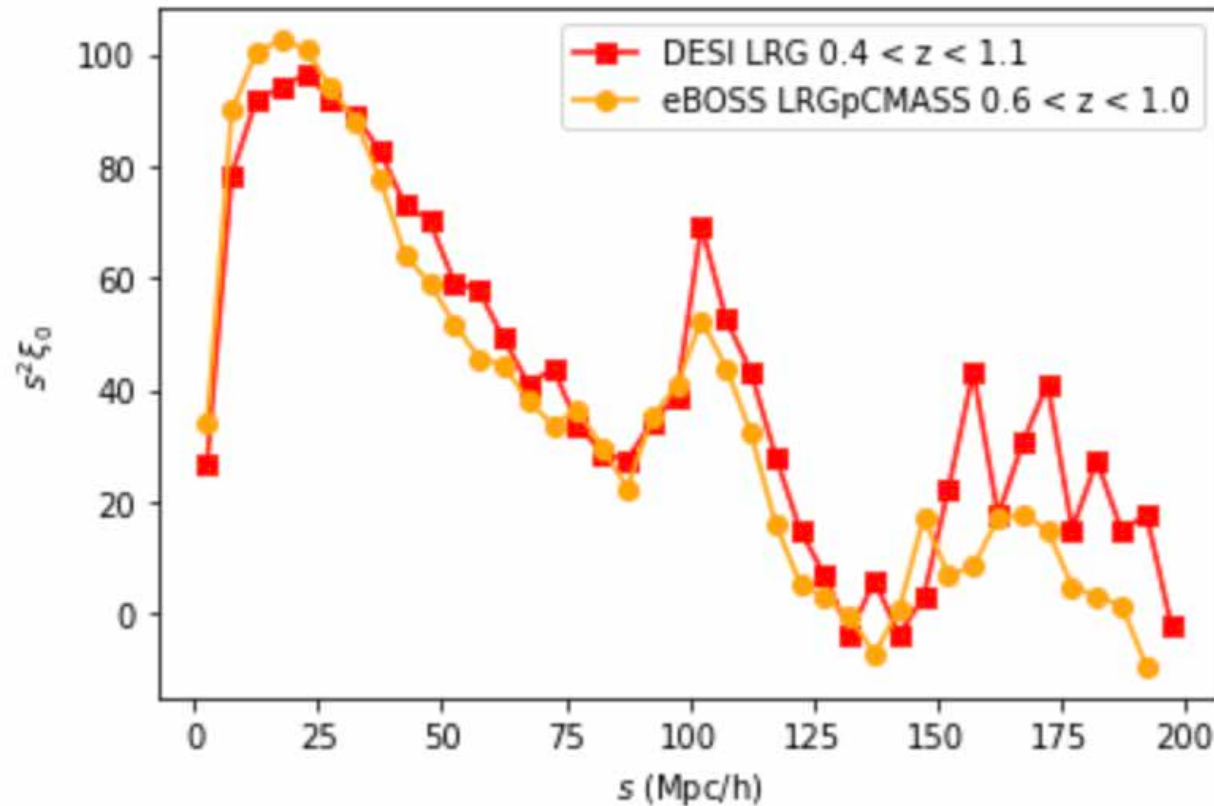
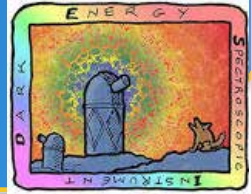
See film at

https://youtu.be/w_DD1z9lqk8

- § “Pie diagram” slice through the universe, with earth in the lower left, looking out to distances beyond 5 billion light years.
- § Each point represents a DESI target.
 - o bright galaxy sample - white points
 - o luminous red galaxies in red
 - o emission line galaxies - in green
 - o quasi-stellar objects - blue
- § Each target ~ 100 billion - 1 trillion stars
- § Gravity has clustered the galaxies into structures called the “cosmic web”, with dense clusters, filaments and voids.



DESI – BAO peak shown in data



BAO peak observed in one target class (LRG's $0.4 < z < 1.1$) from first two months of data. Result is very preliminary.



Vera C. Rubin Observatory



A next-generation, ground-based facility, providing time-lapse imaging of faint astronomical objects across the entire visible sky every few nights.

Discovery Science! 4 primary themes:

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

NSF (AURA) and DOE (SLAC) partnership, with private, international contributions

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

For the first ten years of operations (prime survey), the **Vera C. Rubin Observatory** will carry out the **Legacy Survey of Space and Time (LSST)**, using the DOE's LSST Camera and the **NSF's Simonyi Survey Telescope**.

Due to covid-19, expect delay of about ~ 22 months for overall Observatory completion & data-taking start (now mid 2024)



DOE's LSST Camera – Project Complete!

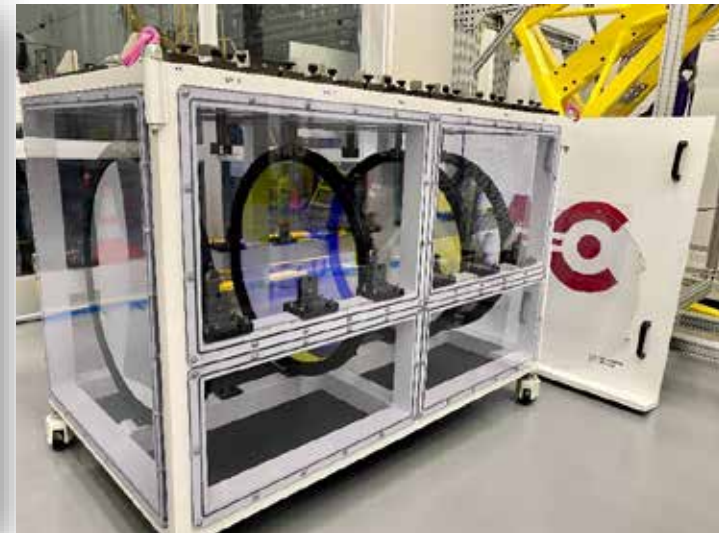
HEP Camera Project Fabrication:

- Due to covid-19 delays & uncertainties, the MIE was restructured to complete at the subsystem level
 - Got CD-4 approval at end of Sept. 2021 (Project Complete)
- Delivery of all the filters to SLAC completed the scope of the LSST Camera project.
- All key performance parameters had previously been demonstrated.



Guinness Book of World Records!

- World's largest digital camera
- L1 lens is world's largest



LSST Camera – Commissioning

HEP Commissioning roles – LSST Camera

- Assembly and verification at SLAC
- Ready to ship to Chile (~ late summer FY2022)
- Ready for for installation and commissioning on telescope (~ early FY2023)

The mass simulator for the Camera arrived successfully on the summit of Cerro Pachón on Sept. 13th. -- Important to test shipping and systems on the mountain



Utility trunk and cryostat was mated and installed on the electro-optical test fixture for integrated testing.



- Refrigeration cool down with the final system was completed successfully and electro-optical testing is expected to start in mid-Nov. and complete by end CY 2022
- Camera shipment practice run from SLAC to the summit was completed successfully and validated the shipment container design ahead of camera shipment expected late summer 2022

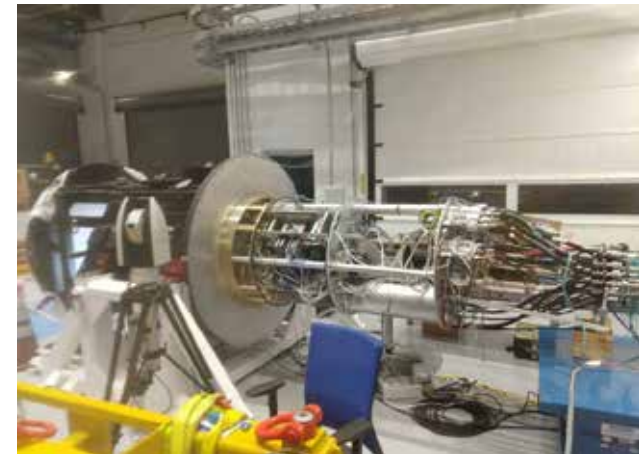
Commissioning Camera



The ComCam is in Chile & has been mated successfully with the refrigeration pathfinder and the quad box.

The commissioning camera (ComCam) was successfully integrated with the rotator as part of early verification of interfaces between the camera and the telescope.

The cold refrigeration pathfinder (chamber seen in the middle of the picture) is running within the commissioning camera.





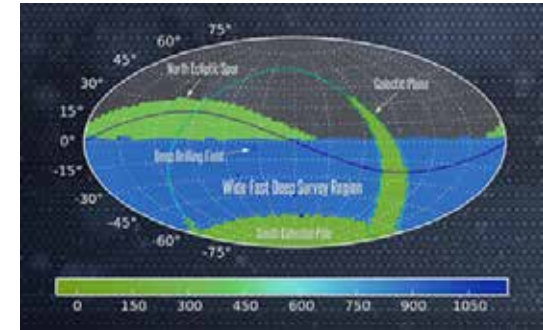
Rubin Observatory: Facility Operations Planning

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

DOE & NSF will provide 50/50 support for operations
- Joint review of Ops plan scheduled for Jan. 2022

DOE-supported operations efforts are primarily:

- o Camera maintenance and operations
- o US Data Facility (USDF) à SLAC selected to be the managing organization
 - o Will carry out the full data facility efforts & deliver all the data products to all researchers and collaborations



International in-kind contributions to operations are in the process of being agreed to - in exchange for early access to data. Types of contributions:

- Offsets to US Operations costs - Priority
- Also consider enhancements to US Science, e.g.
 - o science collaboration software, simulations, data analysis tools
 - o telescope time to US scientists
 - o other data sets or appointments to other collaborations w/o current US access

è Rubin Operations Team is working with contributors to carry out the planning;

NSF & DOE will have final approval.

Scientific Research - Both NSF and DOE will support community efforts
o **DOE's research efforts are organized through DESC**; planning and readiness activities are continuing.



Multiband subfield of Data Challenge 2, from Dark Energy Science Collaboration et al., 2021.

Collaboration ~ 1100 members;
> 235 full members; from 15 countries

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

- § SNe Ia's as "standard candles"
- § Baryon acoustic oscillations as "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

- Provided DESC Data Challenge 2 simulations for use in Rubin Data Preview 0, which is enabling 'delegates' from all LSST Science Collabs to test analyses
- Submitting 4 photometric redshift letters of rec. in response to Rubin call
- Preparing several LOIs for participation in technical validation of Rubin Observatory during Commissioning

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

Cosmic Microwave Background

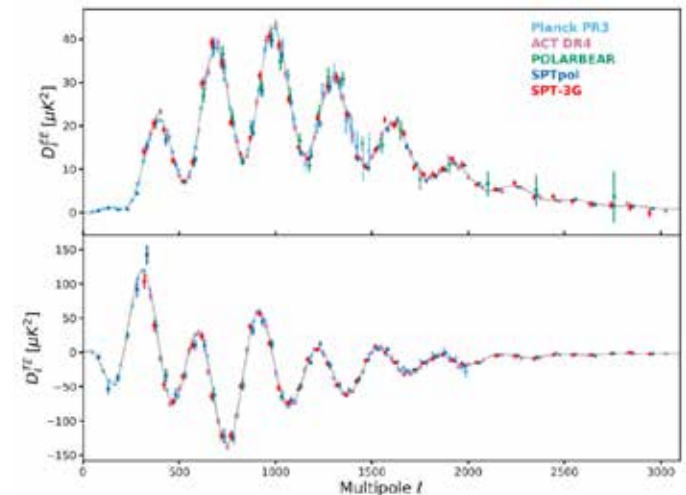
Gain insight into inflationary epoch at the beginning of the universe, dark energy & neutrino properties by studying oldest visible light.

- Ø P5 recommended DOE should support CMB experiments as in the core particle physics program.
- Ø CMB-S4 is intended to be the next flagship Cosmic Frontier project

South Pole Telescope 3rd Generation

- NSF & DOE partnership: HEP supported major upgrade: fabrication of the 16,000-detector focal plane, greatly increasing sensitivity
- Survey started 2018; continues to operate smoothly with high observing efficiency; no covid interruption
- Online transient detection is now working; issuing transient alerts.
- Recent Physical Review D Editor's choice on paper "Constraints on Λ CDM extensions from the SPT-3G 2018 EE and TE" (2021) 10.1103/PhysRevD.104.083509

Publications <https://pole.uchicago.edu/public/Publications.html>



First SPT-3G science publication

- Measurement of TE/EE power spectra w/2018 data

Dutcher et al.

<https://arxiv.org/abs/2101.01684>

Submitted to Physical Review D

Cosmic Microwave Background – Stage 4 (CMB-S4)

CMB-S4 recommended by P5 in all scenarios

- HEP/Cosmic Frontier's next flagship project

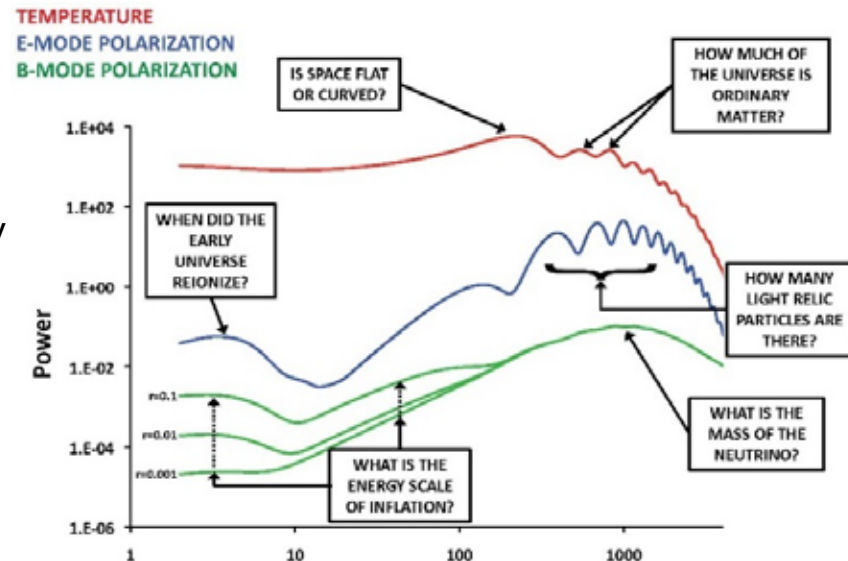
Goal: cross critical science thresholds, including definitive tests of Inflation

Highlights: 2 sites, Chile & South Pole

- § Being planned as a joint DOE/NSF project,
- § Chile: 2 large aperture (6m) telescopes
 - o Deep & wide N_{eff} & Legacy Survey $\sim 60\%$ of sky
- § South Pole: 1 large (5m), 18 small (0.5m)
 - o Ultra-deep survey $\geq 3\%$ of sky + delensing
- § Total 500,000 cryogenic sensors, superconducting readout

Collaboration has > 300 members!

- **July 2019** Project received Critical Decision 0 (CD-0) approval with a $\sim$ \$300 to \$400 million cost range.
- **Aug. 2020**, LBNL chosen as DOE Lead lab; HEP status review
- **Dec. 2020, FY21** budget appropriation provided \$6M for R&D, project development
 - Congress approved it as a Major Item of Equipment (MIE) “project start”

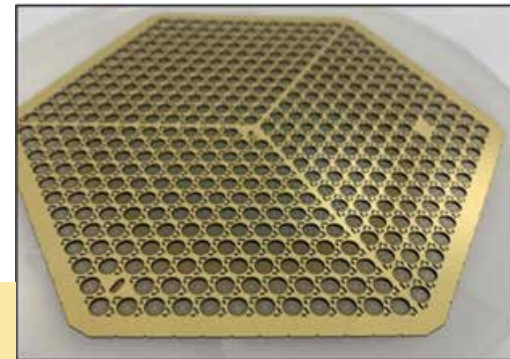


CMB-S4 Status & Plans

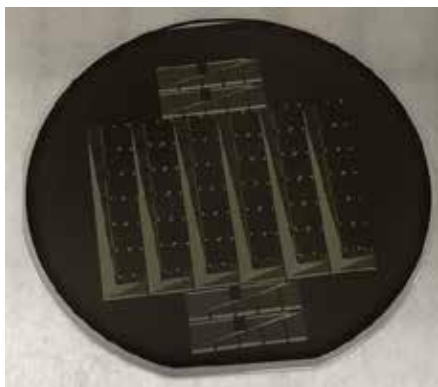
Short term challenge:

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

Following Astro2020 and the agencies' considerations of the recommendations, DOE & NSF can start discussions to consider potential paths forward.



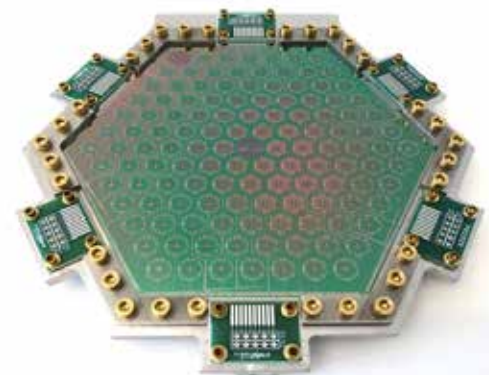
Metalized back side of a prototype CMB-S4 wafer fabricated at ANL



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

Status:

- Completed 8 subsystem conceptual design reviews from May to August.
- DOE Office of Project Assessment status review in February 2022.



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.

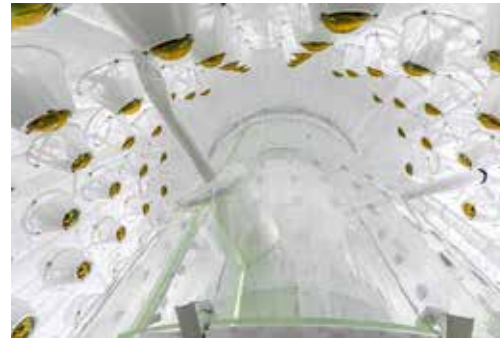


LZ: Direct Detection Dark Matter 2nd Generation project



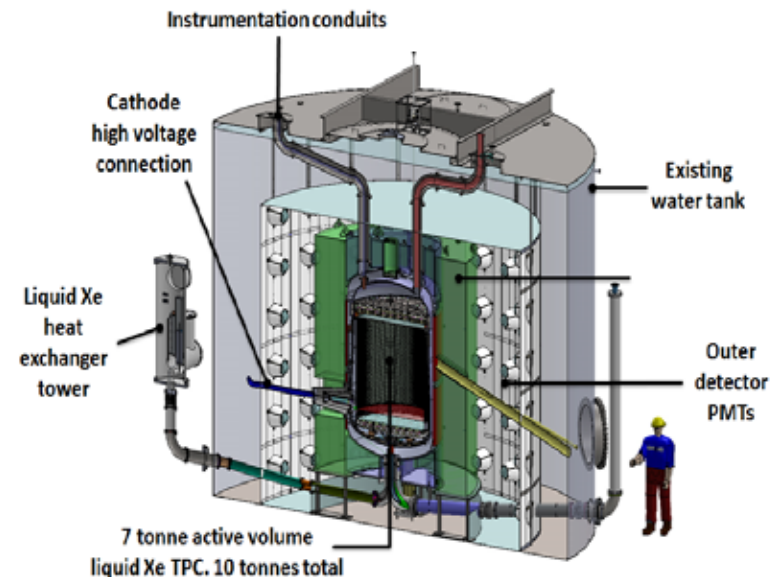
LZ at Homestake Mine in South Dakota – 1 mile underground

- Dual phase liquid Xenon Weakly Interacting Massive Particle (WIMP) search; ~ 10 -1000 GeV mass



LZ Outer detector, completed inner assembly

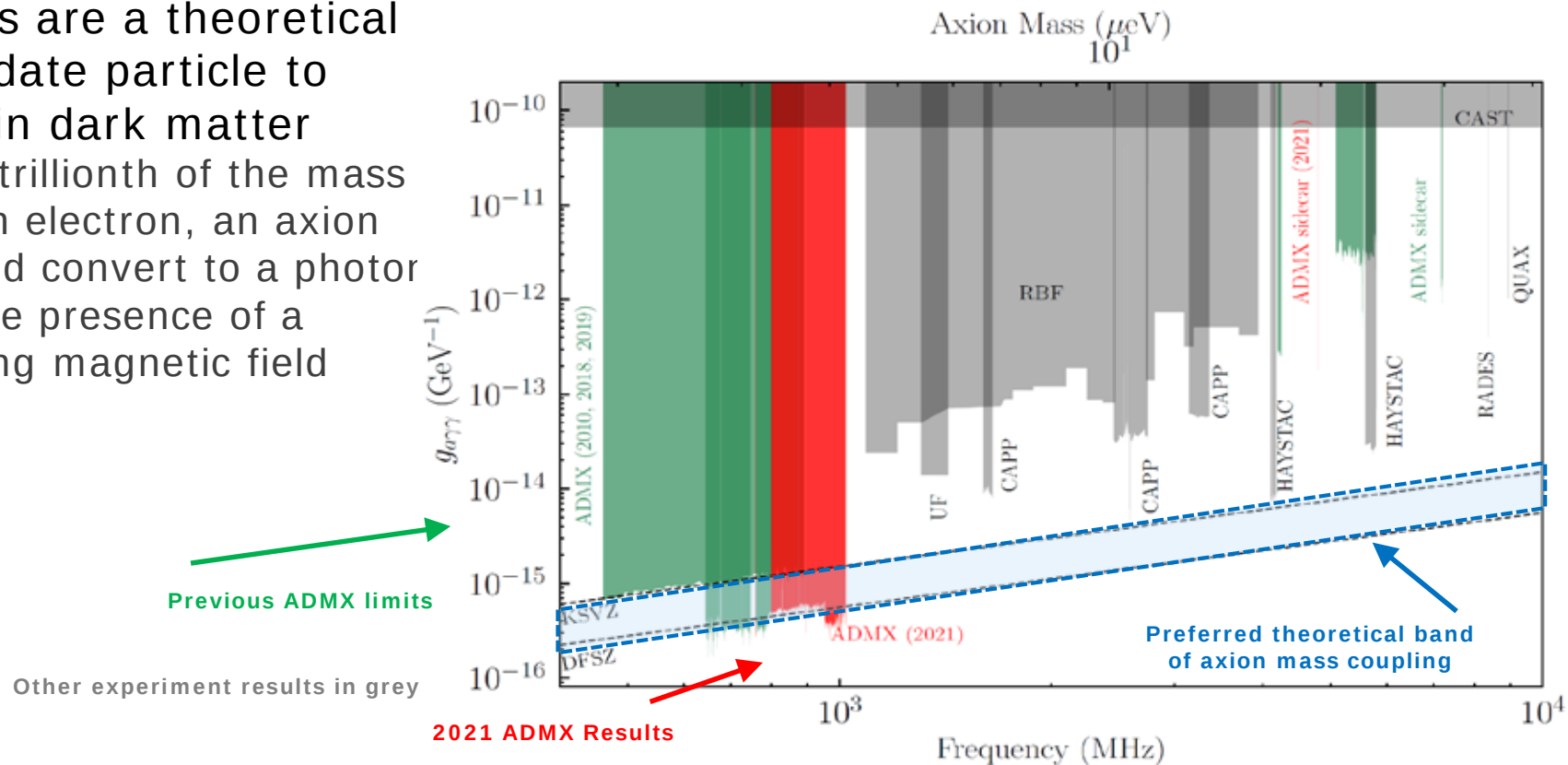
- § Project completed on threshold KPPs (chose this route because of uncertainty due to covid-19); CD-4 Sept. 21, 2020
- § Installation & Commissioning on Operating Funds
- § Commissioning completion & start of science data runs expected to be soon.



ADMX-G2: Direct Detection Dark Matter 2nd Generation project

Axions are a theoretical candidate particle to explain dark matter

} Ten-trillionth of the mass of an electron, an axion would convert to a photon in the presence of a strong magnetic field



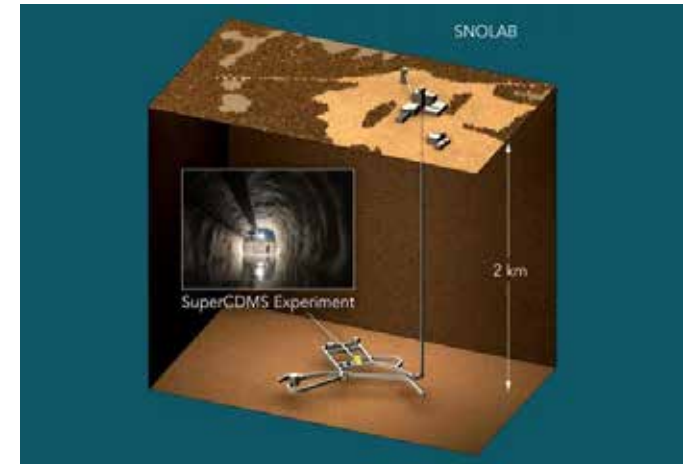
Axion Dark Matter eXperiment Generation 2 operating at U. Washington
2021 results are 5-orders of magnitude better than previous limits, ruling out axion DM hypothesis in this mass-coupling range
Planned upgrades enable continuing search

SuperCDMS SNOLAB: Direct Detection Dark Matter 2nd Generation project



SuperCDMS SNOLAB in Canada at the Creighton nickel mine (HEP+NSF partnership)

- Cryogenic solid-state crystal WIMP search; $\sim 1\text{-}10$ GeV mass
- Project fabrication is being restructured due to issues with cryostat procurement & covid-19
 - The project successfully passed a rebaseline review in September 2021 with a \$6.4M increase in the TPC. DOE will provide \$5.3M, and NSF has been asked for \$1.1M.
- Expect full fabrication completion and full operations start in 2023; Can start operating with partial detector beforehand.

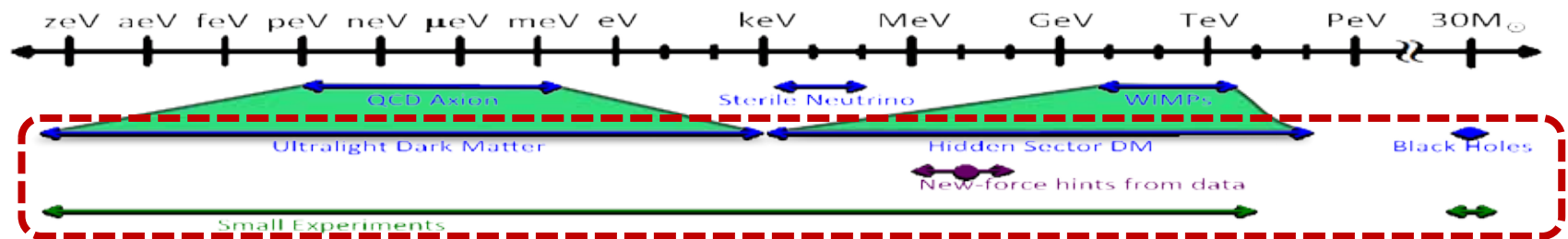


Dark Matter New Initiatives (DMNI)

– Concept Studies for new 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



Dark Matter → 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 potential 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), $<\mu\text{eV}$, K. Irwin (SLAC)
- **TESSERACT** (Multiple detectors, w/TES readout), >10 MeV, D. McKinsey (LBNL)

Intensity Frontier (accelerator based)

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

Annual status review of the DMNI concepts held June 2021.

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+
- Review of MIT/AMS science and operations in Oct. 2021
- 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 in FY2021.



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 any 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:
<https://www.energy.gov/articles/departments-energy-and-nasa-sign-memorandum-understanding>

The 3 focused areas are:

1. Moon (11 papers received)
 - 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. ISS (7 papers received)
 - Small experiments to carry out space-based probes of fundamental physics in a microgravity environment of the International Space Station
3. Rubin+Roman+Euclid joint efforts (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

Cosmic Frontier – Future Planning

Coordination between Rubin, Roman and Euclid

- Community input has been provided via the DOE/NASA RFI (2021).
- Three Agency Group (DOE/NASA/NSF) asked Roman and Rubin leadership, along with the US Euclid leadership, to investigate and prioritize leveraging possibilities.

Astronomy & Astrophysics “Astro2020” Decadal Survey

- DOE will be discussing internally, then later with NSF & NASA.

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 Physics community

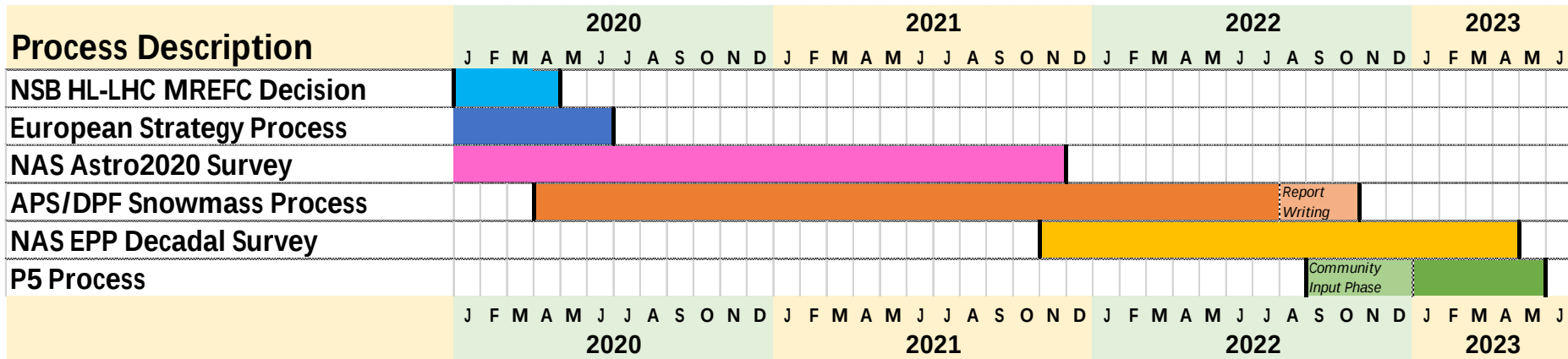
- To identify science questions and directions for the coming decade.
- Process started summer 2019; paused due to COVID and restarted Sept. 2021; and culminates in a workshop in summer 2022.

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.

Strategic Planning Timeline

- } HEP community-wide “Snowmass” study process organized by the Division of Particles and Fields (DPF) of the American Physical Society (APS) has restarted (<https://snowmass21.org/start>)
 - Snowmass process was paused/slowed down due to the COVID; resumed full activities as of September 2021
 - “Community Summer Study” will take place July 17–27, 2022 at UW-Seattle (in-person)
 - Full Snowmass reports will be available by the end of October 2022
- } New National Academy of Sciences (NAS) Elementary Particle Physics (EPP) Decadal Survey will run concurrently with and complement the community-driven Snowmass process
- } Next P5 process to begin after Snowmass and NAS Decadal Survey, circa late 2022: **P5 report by May 2023 will inform FY 2024 Congressional actions & FY 2025 U.S. budget formulation**



Summary

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

à Cosmic Frontier continues to produce excellent, world-leading science results



Future Planning – Astro2020, Snowmass à P5



U.S. DEPARTMENT OF
ENERGY

Office of
Science

BACKUP

- Research (Scientist) Support

HEP University Program – Grant Statistics

Cosmic Frontier – Grant statistics

Cosmic Funding (\$M)	FY16	FY17	FY18	FY19	FY20	FY21
Request (all years)	\$26.47	\$24.60	\$27.61	\$18.28	\$29.31	\$26.01
Request (Year 1)	\$7.80	\$7.60	\$14.32	\$5.22	\$9.15	\$8.32
Funded Year 1, w/FFF	\$4.3M w/FFF	\$4.7M w/FFF	\$5.4M w/FFF	\$3.4M w/FFF	\$4.94 w/FFF	4.72 w/FFF
Cosmic - proposal counts						
received	43	31	30	23	30	27
reviewed	36	26	28	20	30	26
funded	21	18	23	17	23	20
success rate	58%	69%	82%	85%	77%	77%
Cosmic - PI counts						
received	65	49	56	37	51	48
reviewed	55	43	54	34	51	47
funded	25	26	38	27	36	36
success rate	38%	53%	68%	73%	71%	75%

SC Early Career program (Univ + Lab) è FY16-21 Cosmic Frontier Awards

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 

HEP Research Program – For University Grants Funding Opportunity Announcement (FOA) & FAQ

DE-FOA-0002546 issued: August 2, 2021

§ **Six HEP research subprograms**

- Energy, Intensity, and **Cosmic Frontiers**
- HEP Theory, Accelerator R&D, and Detector R&D

§ **Letter of Intent (strongly encouraged) due: August 31, 2021**

§ **Final Proposal deadline: October 5, 2021**

§ **Review and Selection processes: October 2021 to February 2022**

Please read the FOA carefully and comply with all requirements! There is an associated FAQ.

See <https://science.osti.gov/hep/Funding-Opportunities> FOA # 2546

HEP's Annual PI meeting was held Aug. 9-12th.

- Talks by HEP staff on overall program, budget, new initiatives, DEI, funding opportunities, and details of each area, e.g. Cosmic Frontier.
- We encourage you to read over these talks and contact the relevant program manager regarding program details and opportunities.
- See <https://www.orau.gov/heppi2021> -- go to agenda and find the linked talks.

Note: Comparative Review of DOE Lab Research Programs (typically every 4 years; Cosmic Frontier June 2021)

Requirements in the FY2022 HEP FOA

New Appendix:

Recruitment and Retention of Students and Early-Stage Investigators

- Included in research efforts is training of junior scientists (students & postdocs) to enable them successfully complete their research and move to next career step.
- Further, we want to broaden and diversify the HEP research community and increase opportunities for everyone to contribute.
- A new merit criterion has been added for proposal evaluation:
Quality and Efficacy of Recruitment and Mentoring Plan

Data Management Plan (DMP)

All Research proposals submitted to DOE SC must have a DMP

- § Data management involves all stages of the digital data life cycle: capture, analysis, sharing, and preservation. The SC Digital Data Management Statement focuses on sharing and preserving digital research data.

Other DOE 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
 - } Two calls per year, usually Feb/Aug
 - } Applications typically due May/Nov for following Fall or Summer start
- } **Science Undergraduate Laboratory Internships (SULI)**
 - } Supports undergraduate research at a DOE lab, 10 to 16 weeks
 - } Three calls per year, for following Spring/Summer/Fall terms
- } **Visiting Faculty Program**
 - } Summer research support for faculty/students from historically underrepresented institutions
 - } One call per year, usually in Oct. Applications due in Jan.

*Available funds have
been increasing!*

Office of Science programs:

- } **Early Career Research:** <https://science.osti.gov/early-career>
 - } FY 2022 FOA #2563 released 9/9/21; pre-applications due 10/21/21, full proposals due 1/20/22.
- } **SC “Open Call”** [DE-FOA-0002414] – new version posted annually
 - } HEP uses this primarily for conferences, supplements, experimental operations, and emergencies (e.g. equipment failure).



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