Cosmic Frontier Experimental Program

DOE/HEP report to the NAS-CAA

March 18, 2024

Kathy Turner
U.S. Department of Energy
Office of High-Energy Physics

U.S. DEPARTMENT OF ENERGY | Office of Science

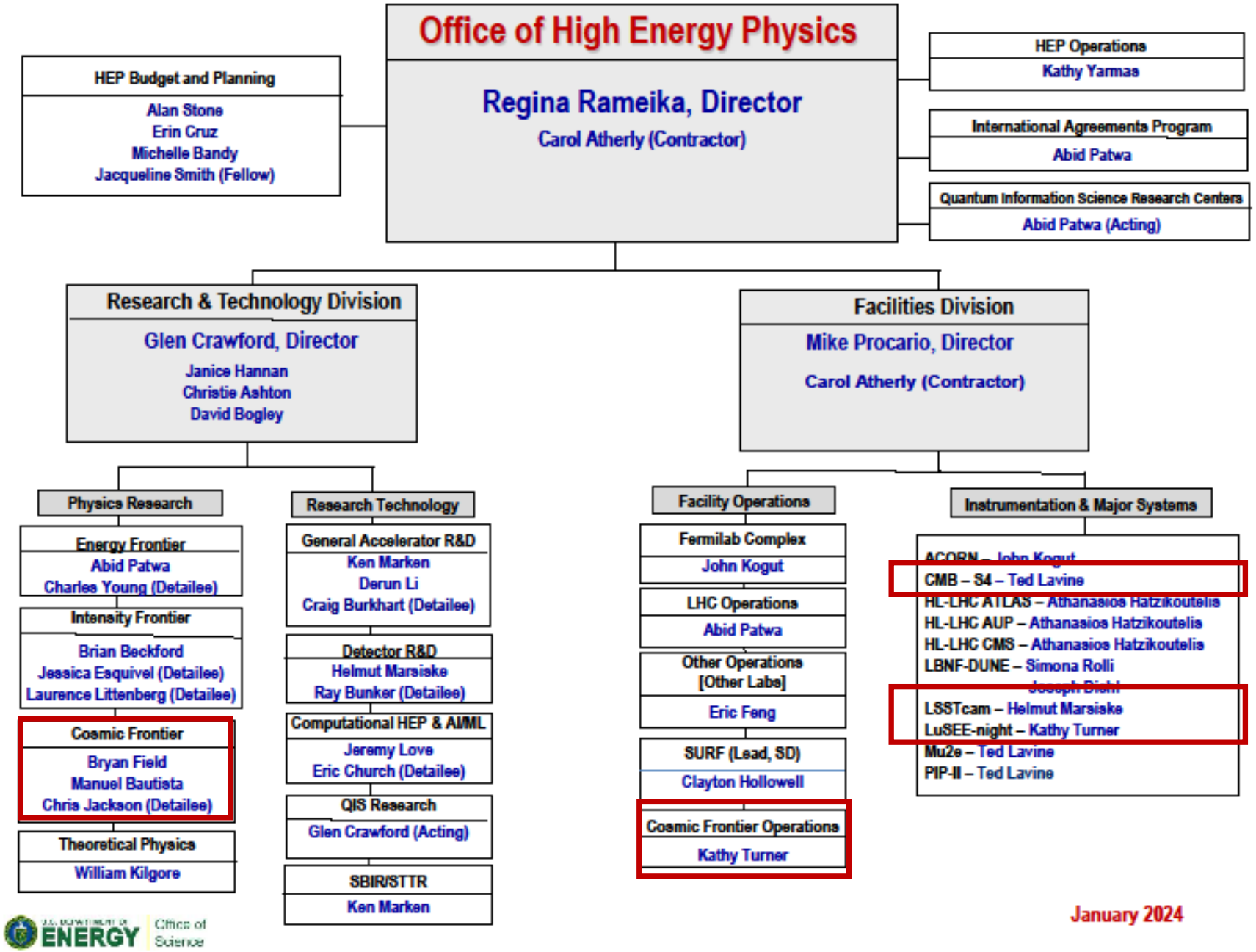
U.S. DEPARTMENT OF ENERGY | Office of Science

OUTLINE

- HEP News, Program Guidance
- Budget
- HEPAP Studies/Reports
  - International Benchmarking
  - P5
  - Facility and COV subpanels
- Cosmic Frontier Program Status
- DEI/Outreach, Energy Sustainability

U.S. DEPARTMENT OF ENERGY | Office of Science

HEP News, Program Guidance


Office of High Energy Physics
Regina Rameika, Director
Carol Atherly (Contractor)
HEP Budget and Planning
Alan Stone
Erin Cruz
Michelle Bandy
Jacqueline Smith (Fellow)
HEP Operations
Kathy Yarmas
International Agreements Program
Abid Patwa
Quantum Information Science Research Centers
Abid Patwa (Acting)
Research & Technology Division
Glen Crawford, Director
Janice Hannan
Christie Ashton
David Bogley
Facilities Division
Mike Procario, Director
Carol Atherly (Contractor)
Physics Research
Energy Frontier
Abid Patwa
Charles Young (Detailee)
Intensity Frontier
Brian Beckford
Jessica Esquivel (Detailee)
Laurence Littenberg (Detailee)
Cosmic Frontier
Bryan Field
Manuel Bautista
Chris Jackson (Detailee)
Theoretical Physics
William Kilgore
Research Technology
General Accelerator R&D
Ken Marken
Derun Li
Craig Burkhart (Detailee)
Detector R&D
Helmut Marsiske
Ray Bunker (Detailee)
Computational HEP & AIML
Jeremy Love
Eric Church (Detailee)
QIS Research
Glen Crawford (Acting)
SBIR/STTR
Ken Marken
Facility Operations
Fermilab Complex
John Kogut
LHC Operations
Abid Patwa
Other Operations [Other Labs]
Eric Feng
SURF (Lead, SD)
Clayton Hollowell
Cosmic Frontier Operations
Kathy Turner
Instrumentation & Major Systems
ACORN – John Kogut
CMB – S4 – Ted Lavine
HL-LHC ATLAS – Athanasios Hatzikoutelis
HL-LHC AUP – Athanasios Hatzikoutelis
HL-LHC CMS – Athanasios Hatzikoutelis
LBNF-DUNE – Simona Rolli
Joseph Biehl
LSSTcam – Helmut Marsiske
LuSEE-night – Kathy Turner
Mu2e – Ted Lavine
PIP-II – Ted Lavine
ENERGY
Office of Science
January 2024

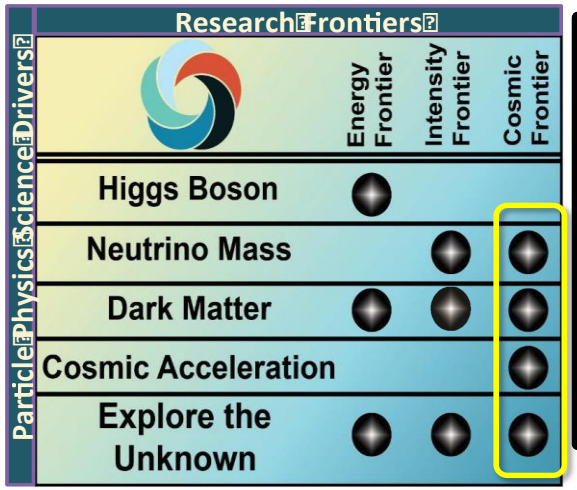
Guidance used to Develop Program

HEPAP - reports to DOE & NSF **AAAC – reports to NASA, NSF, DOE**

HEPAP/PASAG (2009) – gave criteria we use to determine HEP roles & responsibilities

NAS/Astro2010 recommended DOE/NSF partnership on LSST (Rubin)

HEPAP/P5 (2014) strategic plan recommended science & project priorities aligned with the P5 science drivers -- in Dark Energy, Dark Matter, CMB projects + small projects.

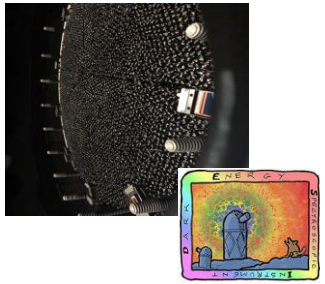


- **Cosmic Acceleration:**
  - **Dark Energy**: build **LSST (Rubin) & DESI**
  - **CMB**: support as part of the core program within multi-agency context; carry out multi-agency **CMB-S4** project later in the decade
- **Dark Matter:** suite of "generation 2" direct detection dark matter searches
- **Neutrino Mass** – survey experiments → info on neutrino properties
- **Explore the Unknown** – always of interest!

NAS/Astro2020 recommended:

- **DOE/NSF partnership on CMB-S4**
- **Dark Ages** identified as Discovery Area → cosmological probe with great potential
- Efforts on diversity, equity, inclusion, demographics, data, etc. (joint with NSF & NASA)

Cosmic Frontier:
Current Program Based on 2014 P5 recommendations is Continuing



Cosmic Acceleration – Phases of the Cosmos

- Nature of **Dark Energy** using imaging & spectroscopic surveys
  - Stage 3 - ***eBOSS*** *(completed 2020)*, **DES** doing final data analyses
  - **Stage 4 - DESI** (operating)
    - **LSST** Camera (completed, now commissioning) for Rubin Observatory (ops planning; survey starts ~ mid-2025) with **DESC** (planning)
- Using the CMB to peer into era of **Inflation** with **SPT-3G (operating), CMB-S4 (concept design)**

Dark Matter:

- Direct Detection searches (WIMPs, Axions) using a variety of methods and technologies:
  ADMX-G2, LZ, SuperCDMS SNOLAB, Dark Matter New Initiative (DMNI) concepts
- Indirect searches: ***VERITAS, HAWC,*** **Fermi-LAT** (now ops only), **AMS** on ISS

Small Projects: Search for the **Dark Ages** signal using **LuSEE-Night** pathfinder
Neutrino properties constrained using dark energy & CMB measurements
Exploring the Unknown - Always interested in New Physics!

Black: HEP support ended
Green: support continues

Recommended by 2014 P5

Recent, Future Program Guidance

HEPAP subpanels – Recent/Current

- **HEPAP International Benchmarking study – completed Nov. 2023**
- **HEPAP Particle Physics Project Prioritization Panel (P5) study – completed Dec. 2023 – will be used for future program planning**
  - Used as input: European physics strategy, Astro2020, Snowmass report etc

2 new studies, with charges described at the Dec. 2023 HEPAP mtg
https://science.osti.gov/-/media/hep/hepap/pdf/Meetings/2023/New-Charges-for-HEPAP.pdf

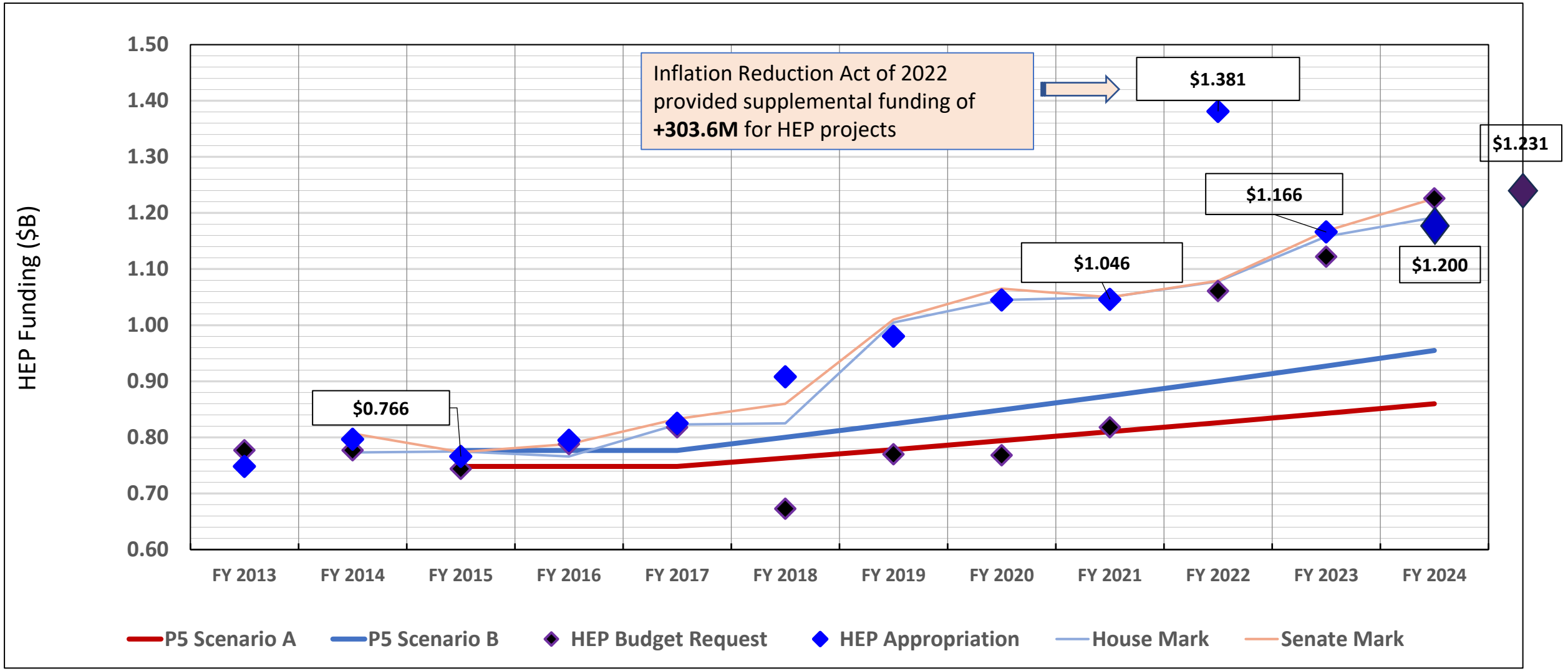
- Committee of Visitors (COV) for the HEP Facilities Division
- Office of Science wide Facilities Construction Project subpanel study

National Academies study continuing: Elementary Particle Physics 2024 (EPP2024)
https://www.nationalacademies.org/our-work/elementary-particle-physics-progress-and-promise

U.S. DEPARTMENT OF ENERGY | Office of Science

BUDGET

HEP Budget History 2013 to Present



- U.S. Congress continues to show strong support for executing the 2014 P5 strategy, and for accelerating the pace of projects

HEP Budget FY23-25

		FY23 Enacted	FY24 Request	FY24 Approved March 2024	FY25 Request March 2024
Energy Frontier		180.833	161.533		150.268
Intensity Frontier		273.199	266.241		275.209
Cosmic Frontier	**Res**	**51.552**	**49.512**		**36.301**
	Ops	**56.550**	**61.830**		**57.210**
	MIE	1.000	9.000		4.500
Theory		171.746	173.746		186.714
Adv Tech R&D		133.120	128.472		115.566
Res, Ops, R&D, MIE		**868.000**	**850.334**	**824.000**	**825.768**
Construction		**298.000**	**376.000**	**376.000**	**405.000**
HEP Total		**1,166.000**	**1,226.334**	**1,200.000**	**1,230.768**
SC TOTAL		**8,100.000**	**8,800.400**	**8,240.000**	**8,583.000**

HIGH ENERGY PHYSICS

The agreement provides not less than $35,000,000 for the Sanford Underground Research Facility and not less than $5,000,000 for the Accelerator Controls Operations Research Network.

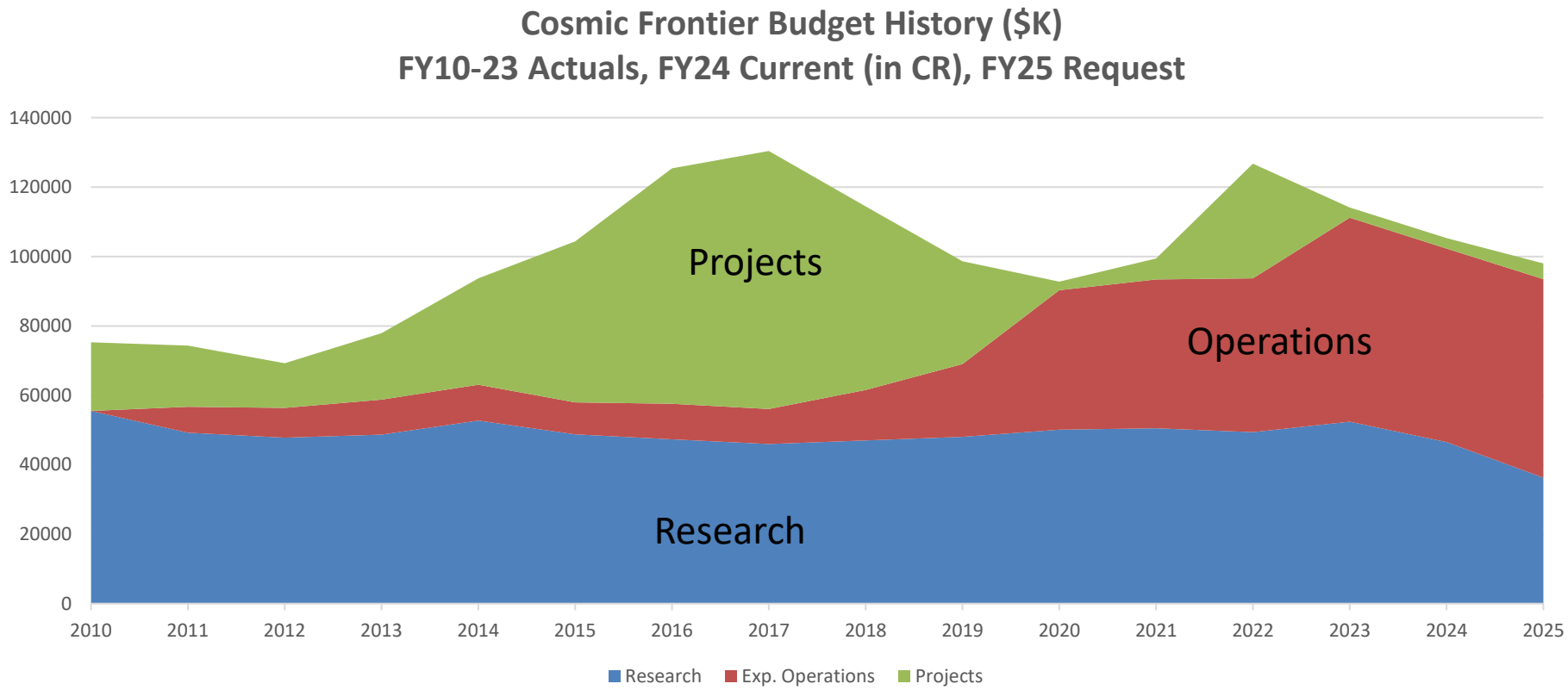
Cosmic Frontier Budget FY2021 – FY2025

Cosmic Frontier ($K)	FY2021 Actual	FY2022 Actual	FY2022 Inflation Reduction Act	FY2023 Actual	FY2024 Request	FY2024 Current (in CR)	FY2025 Request
Research	50,521	49,395		52,417	48,048	46,511	36,301
Research (Univ+Lab)	*43,901*	*42,513*		*45,698*		*39,560*	
Future R&D	*1,700*	*1,475*		*1,979*		*1,986*	
AI/ML Research	4,920	5,407		4,740		4,965	
Exp. Ops.	42,880	44,350		58,810	61,830	55,780	57,210
Projects: CMB-S4, LuSEE-Night (FY22)	6,000	23,000	11,893	1,000	9,000	3,000	4,500
Total	**99,401**	**116,745**	**11,893**	**108,227**	**120,342**	**105,291**	**98,011**

NOTES:

- The amounts shown in the table do not include workforce costs or SBIR/STTR funds.
- FY 23 Request was $92.9M

Cosmic Frontier Budget History



FY22 Project includes funds from the Inflation Reduction Act

- Research: Scientist support for efforts in design, construction, operations & data analysis
- Experimental Operations: Commissioning and data-taking operations
- Projects: CMB-S4 planning, LuSEE-Night (all funds in FY22); SuperCDMS completed in FY23
- Future opportunities: Compelling Cosmic Frontier Projects will be considered and supported within available overall HEP project funds. Guidance from Astro2020, Snowmass, P5 (2023)

U.S. DEPARTMENT OF ENERGY | Office of Science

HEPAP International Benchmarking report (Nov2023)

HEPAP International Benchmarking study

Presentation to HEPAP (11/2/23)
https://science.osti.gov/-/media/hep/hepap/pdf/202311/HEPAPBenchmarking_Nov_2023.pdf
Report → https://science.osti.gov/-/media/hep/hepap/pdf/202203/International_Benchmarking_HEPAP_2023112.pdf

Findings and Recommendations were provided in 3 main areas, with 7 sets of findings, *recommendations*

A. Collaboration - *Science enabled by partnerships, experiments, and facilities*

1. Scientific breadth and application

Particle physics theory and experiments address deep mysteries of the universe while advancing concepts and technology that are vital to other research fields, as well as society at large.

Strengthen investments to advance particle physics discoveries as well as benefits to other scientific disciplines and society.

2. Diversity across scales and stages

The field of particle physics is a vibrant research ecosystem, built by an international network of partnering nations, facilities, experiments, and people. To be a leader, the U.S. must continuously produce scientific results, build facilities and experiments for the future, and advance new ideas and technologies that enable the discoveries of tomorrow.

Maintain a comprehensive program at home and abroad, with a range of experiment scales and strategic balance among construction projects, operations of experiments and facilities, and core research activities, including development of future facilities.

HEPAP International Benchmarking study

3. Collaborating across the globe

Frontier research in particle physics necessitates international collaboration and cooperation. The combined expertise and resources from nations around the world enable discoveries and technological advances impossible to achieve by any single nation. It is the *global* particle physics program that collectively addresses the burning scientific questions across the breadth of the field.

Continue support for and actively seek engagement with international collaborations and partnerships of all sizes.

4. Being a partner of choice

Success in hosting and participating in international collaborations requires tailored approaches to collaboration governance and project management, host lab environments that are conducive to international research teams, and the ability to make reliable agreements with international partners.

Implement structures for hosting strong international collaborations, act with timeliness, consistently meet obligations, and facilitate open communication with partners.

HEPAP International Benchmarking study

B. Enabling Capabilities and Technologies - *Science enabled by new tools, techniques and national initiatives*

5. Strengthening critical capabilities

It is our state-of-the-art expertise in the tools, technology, and techniques of particle physics that makes the U.S. a sought-after partner and gives us the ability to impact future experiments at home and abroad.

Continuously develop critical technologies to maintain and grow U.S. leadership in particle physics at home and abroad.

6. Advancing National Initiatives

The national initiatives in artificial intelligence and machine learning, quantum information science, and microelectronics are accelerating new research avenues in particle physics, and particle physics contributions to these initiatives are bringing new ideas and new technologies to a range of disciplines.

Enhance and leverage the innovative role that particle physics plays in artificial intelligence and machine learning, quantum information science, and microelectronics to advance both particle physics and these national initiatives.

C. Workforce - *Attracting and retaining a talented, highly trained, and diverse U.S. workforce*

7. Building a robust workforce

Attracting, inspiring, training, and retaining a diverse workforce is vital to the success of all particle physics endeavors and more broadly, to U.S. science and technology. A robust particle physics workforce will both leverage and be representative of the diversity of the nation.

Explore frontier science using cutting-edge technologies to inspire the public and the next generation of scientists while opening new pathways to diversify the workforce and realize the full potential of the field.

U.S. DEPARTMENT OF ENERGY | Office of Science

P5 report

HEPAP 2023 December P5 report

DOE/HEP thanks the panel for the tremendous job they did over the last year leading to this excellent report.

- It will take a while for DOE to read the report and develop plans based on the recommendations.
- New program directions will likely take a few years to be implemented.

Charge

https://science.osti.gov/-/media/hep/hepap/pdf/202212/2022-601_Charge_Letter_P5-2022_AAB_and_SJ_Signed.pdf - 2 funding scenarios provided by HEP

- developing a 10-year strategic plan for US particle physics, in the context of a 20-year global strategy and two constrained budget scenarios.

An essential source of input was the 2021 Snowmass Community Planning Exercise organized by the Division of Particles and Fields of the APS. Astro2020, the European strategic plan etc – also used as input.

➔See Hitoshi Murayama's P5 report talk at the Dec. 2024 AAAC meeting

12/7/23 P5's presentation to HEPAP

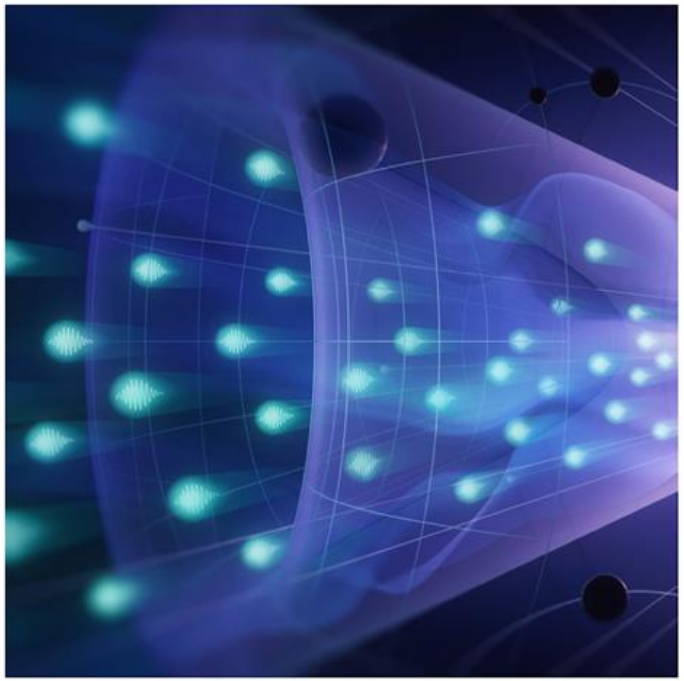
https://science.osti.gov/hep/hepap/Meetings/202312

12/8/23 draft report (draft approved by HEPAP but there may be some wording updates)

https://science.osti.gov/-/media/hep/hepap/pdf/Reports/P5Report2023_120123-DRAFT-to-HEPAP.pdf

Or see 2023p5report.org

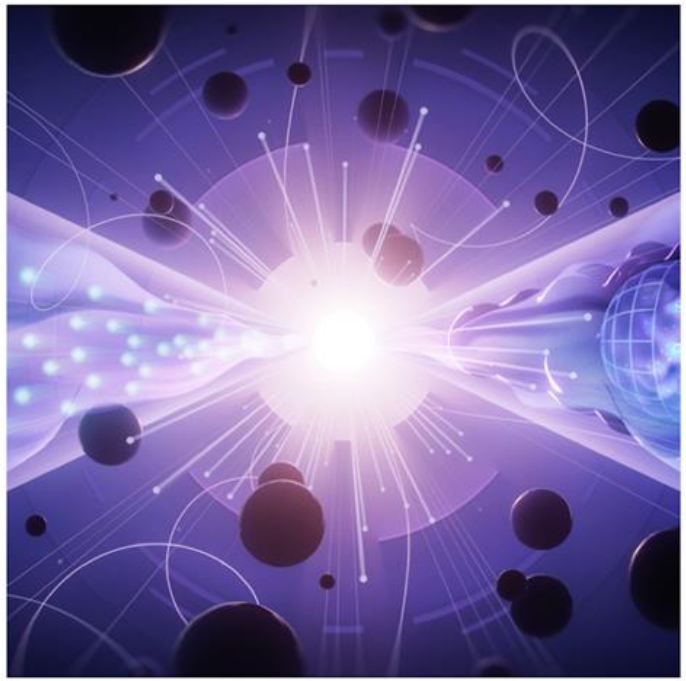
P5 identified 3 science themes, 6 science drivers



Decipher the Quantum Realm

Elucidate the Mysteries of Neutrinos

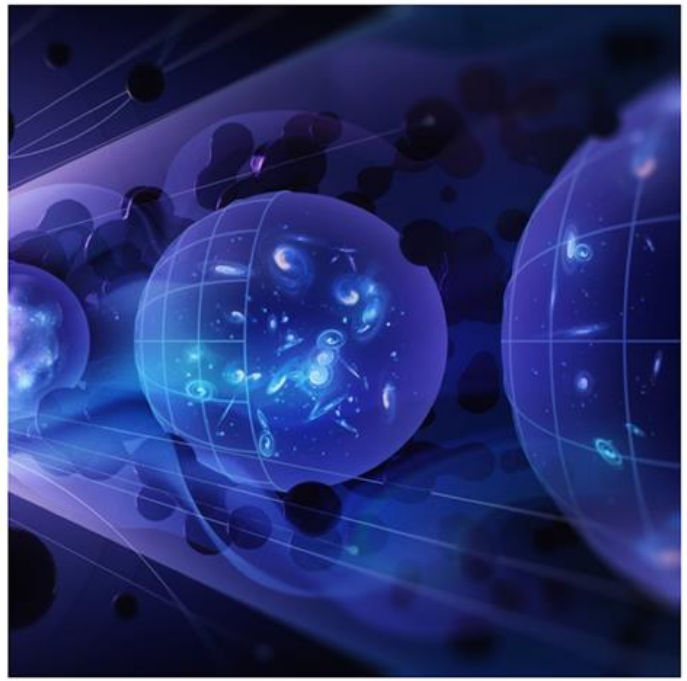
Reveal the Secrets of the Higgs Boson



Explore New Paradigms in Physics

Search for Direct Evidence of New Particles

Pursue Quantum Imprints of New Phenomena



Illuminate the Hidden Universe

Determine the Nature of Dark Matter

Understand What Drives Cosmic Evolution

2023 P5 Report

The panel categorized projects as small (<$50M), medium ($50M–250M), and large (>$250M) based on the US contribution to their construction cost.

- In the large and medium categories, initiatives were first prioritized based on individual scientific merit, then assessed on project maturity, technical risk, and balance of project timescales.
- For the small category, the panel generally did not consider individual projects but did note areas where these could be particularly effective.

The panel made six recommendations.

P5 recommendations

1) As the highest priority independent of the budget scenarios, complete construction projects and support operations of ongoing experiments and research to enable maximum science. This includes support for

- HL-LHC (including ATLAS and CMS detectors, as well as Accelerator Upgrade Project) to start addressing why the Higgs boson condensed in the universe (*reveal the secrets of the Higgs boson*), to *search for direct evidence for new particles*, to *pursue quantum imprints of new phenomena,* and to *determine the nature of dark matter*.
- The first phase of DUNE and PIP-II to determine the mass ordering among neutrinos, a fundamental property and a crucial input to cosmology and nuclear science (*elucidate the mysteries of neutrinos*).
- **The Vera C. Rubin Observatory to carry out the LSST, and the LSST Dark Energy Science Collaboration, to *understand what drives cosmic evolution*.**
- NOvA, SBN, and T2K (*elucidate the mysteries of neutrinos*).
- DarkSide-20k, **LZ, SuperCDMS**, and XENONnT (determine the nature of dark matter).
- **DESI** (*understand what drives cosmic evolution*).
- Belle II, LHCb, and Mu2e

P5 recommendations

2) Construct a portfolio of major projects that collectively study nearly all fundamental constituents of our universe and their interactions, as well as how those interactions determine both the cosmic past and future. Plan and start the following major initiatives in order of priority from highest to lowest:

- **CMB-S4, which looks back at the earliest moments of the universe to probe physics at the highest energy scales. It is critical to install telescopes at and observe from both the South Pole and Chile sites to achieve the science goals.**
- Re-envisioned second phase of DUNE with an early implementation of an enhanced 2.1 MW beam—ACE-MIRT—a third far detector, and an upgraded near-detector complex as the definitive long-baseline neutrino oscillation experiment of its kind.
- An off-shore Higgs factory to reveal the secrets of the Higgs boson. The current designs of FCC-ee and ILC meet our scientific requirements. The US should aim for a contribution at funding levels commensurate to that of the US involvement in the LHC and HL-LHC.
- **An ultimate Generation 3 (G3) dark matter direct detection experiment reaching the neutrino fog, in coordination with international partners and preferably sited in the US.**
- IceCube-Gen2 for study of neutrino properties using non-beam neutrinos complementary to DUNE and for indirect detection of dark matter covering higher mass ranges using neutrinos as a tool

P5 recommendations

3) Create an improved balance between small-, medium-, and large-scale projects to open new scientific opportunities, enhance workforce development, promote creativity, and compete on the world stage. To achieve this balance the recommendation is to:

- Implement a new small-project portfolio at DOE, Advancing Science and Technology through Agile Experiments (ASTAE), across science themes in particle physics with a competitive program and recurring funding opportunity announcements. This program should start with the construction of experiments from the **Dark Matter New Initiatives (DMNI)** by DOE-HEP.
- Continue Mid-Scale Research Infrastructure (MSRI) and Major Research Instrumentation (MRI) programs.
- Support **DESI-II** for cosmic evolution, LHCb upgrade II and Belle II upgrade for quantum imprints, and US contributions to the global CTA Observatory for dark matter

P5 recommendations

4: Support a comprehensive effort to develop the resources—theoretical, computational, and technological—essential to our 20-year vision for the field. This includes an aggressive R&D program that could yield revolutionary accelerator designs that chart a realistic path to a 10 TeV pCM collider. This requires the following:

- Support R&D toward a cost-effective 10 TeV pCM collider based on proton, muon, or possible wakefield technologies, including an evaluation of options for US siting of such a machine, with a goal of being ready to build major test facilities and demonstrator facilities within the next 10 years.
- Enhance research in theory to propel innovation, maximize scientific impact of investments in experiments, and expand our understanding of the universe.
- Expand the General Accelerator R&D (GARD) program within HEP, including stewardship.
- Invest **in R&D in instrumentation** to develop innovative scientific tools.
- Conduct R&D efforts to define and enable new projects in the next decade, including detectors for an *e*+*e*– Higgs factory and 10 TeV pCM collider, **Spec-S5**, DUNE FD4, Mu2e-II, Advanced Muon Facility, and line intensity mapping.
- **Support key cyberinfrastructure components** such as shared software tools and a sustained R&D effort in computing to fully exploit emerging technologies for projects.
- Prioritize computing and novel data analysis techniques for maximizing science across the entire field.
- Develop plans for improving the Fermilab accelerator complex that are consistent with the long-term vision of this report, including neutrinos, flavor, and a 10 TeV pCM Collider.

P5 recommendations

5) Invest in initiatives aimed at developing the workforce, broadening engagement, and supporting ethical conduct in the field. This includes:

- All projects, workshops, conferences, and collaborations must incorporate ethics agreements that detail expectations for professional conduct and establish mechanisms for transparent reporting, response, and training. These mechanisms should be supported by laboratory and funding agency infrastructure. The efficacy and coverage of this infrastructure should be reviewed by a HEPAP subpanel.
- Funding agencies should continue to support programs that broaden engagement in particle physics, including strategic academic partnership programs, traineeship programs, and programs in support of dependent care and accessibility. A systematic review of these programs should be used to identify and remove barriers.
- Comprehensive work-climate studies should be conducted with the support of funding agencies. Large collaborations and national laboratories should consistently undertake such studies. Professional associations should spearhead field-wide work-climate investigations.
- Funding agencies should strategically increase support for research scientists, research hardware and software engineers, technicians, and other professionals at universities.
- A plan for dissemination of scientific results to the public should be included in the proposed operations and research budgets of experiments. The funding agencies should include funding for the dissemination of results to the public in operation and research budgets.

P5 recommendations

6) Convene a panel across particle physics that makes decisions on the US accelerator-based program at the time when major decisions concerning an off-shore Higgs factory are expected, and/or significant adjustments within the accelerator-based R&D portfolio are likely to be needed. A plan for the Fermilab accelerator complex consistent with the long-term vision in this report should also be reviewed. The panel would consider:

- The level and nature of US contribution in a specific Higgs factory including an evaluation of the associated schedule, budget, and risks once crucial information becomes available.
- Mid- and large-scale test and demonstrator facilities in the accelerator and collider R&D portfolios.
- A plan for the evolution of the Fermilab accelerator complex, which may commence construction in the event of a more favorable budget situation.

U.S. DEPARTMENT OF ENERGY | Office of Science

SC Facilities Subpanel

Office of Science (SC) Facilities subpanel

Follow on to previous SC-wide prioritization studies that were carried out in 2004 & 2013

Charge letter (12/1/23) → https://science.osti.gov/-/media/hep/hepap/pdf/2023-Berhe-Facilities-Charge.pdf

-- Each of the 6 SC panels will carry out a subpanel study, complete by May 2024

- **Similar criteria to the previous charges.**
  - The potential to contribute to world-leading science in the next decade.
  - The readiness for construction.
- **"In its deliberations, the subcommittee should reference relevant strategic planning documents and decadal studies."**

HEP supplied a list of pre-CD3 projects over $100M to consider (though the panel may add more)

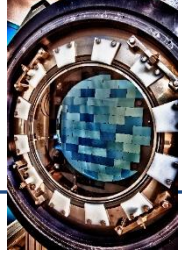
- Near term: LBNF/DUNE (has 5 subprojects), CMB-S4
- Mid term: Accelerator Complex Enhancement Main Injector Target (ACE-MI+T), Advanced Accelerator test facilities, DUNE far detector upgrade
- Far term: Future Energy Frontier collider, DUNE near detector upgrade, Stage 5 Spectroscopic Survey Instrument, Accelerator Complex Booster replacement

U.S. DEPARTMENT OF ENERGY | Office of Science

Cosmic Frontier

- Program Update

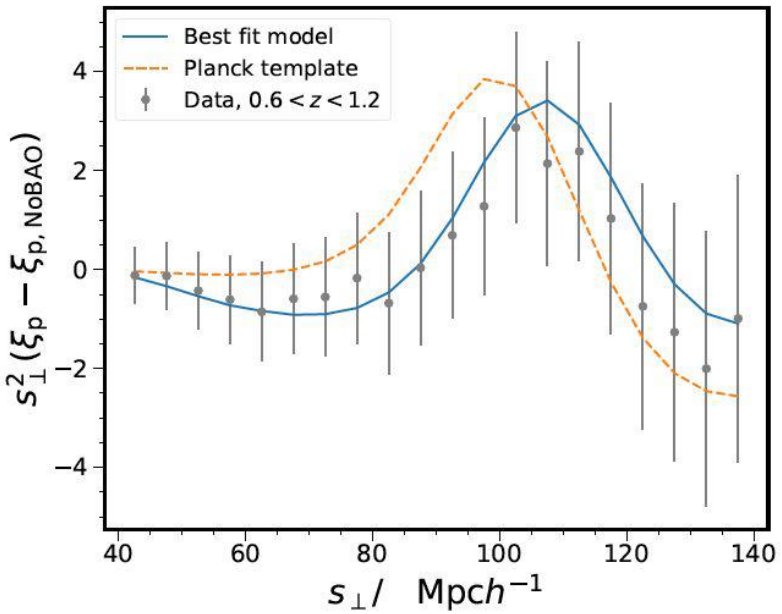
*Dark Energy Survey (DES) – Stage III imaging survey

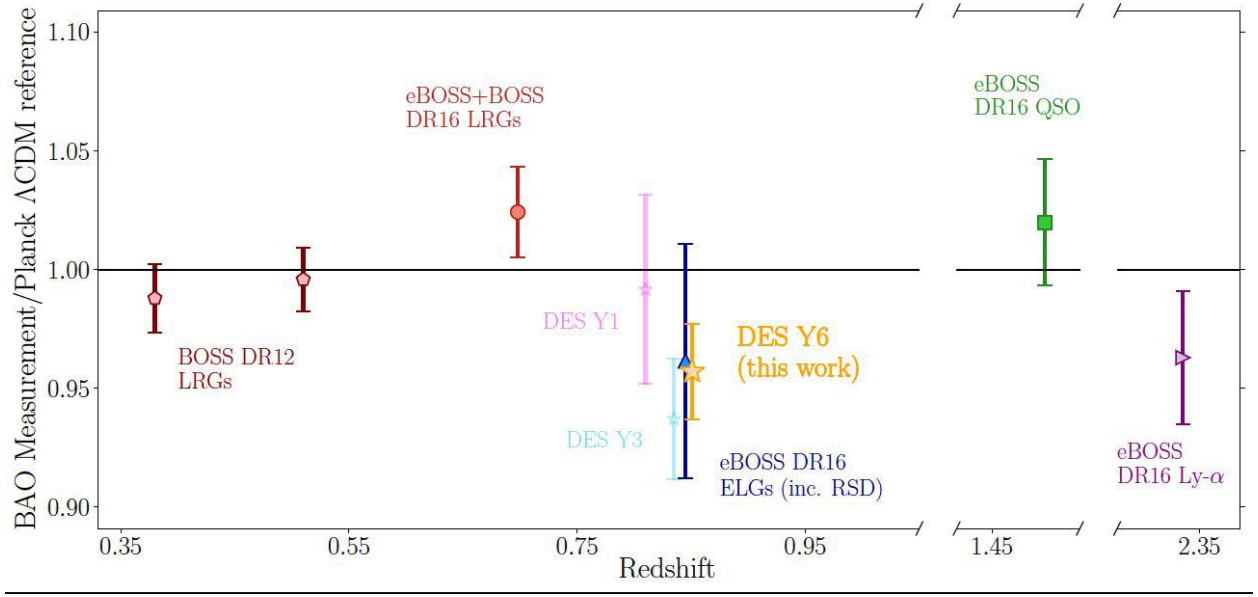


DARK ENERGY SURVEY

DOE-HEP & NSF-AST partnership; had JOG & joint reviews
DOE (Fermilab) led fabrication of 570Mpix DECam; NSF led telescope upgrades, data management system
Operations: 6-year imaging survey of 5100 sq-deg completed Jan. 2019
Plan forward: now final data processing and analysis (> 425 publications)
Final results from all Year 3 data end of 2024; all Year 6 data ~ 2025++

➔ HEP supporting FNAL to store and publicly serve the cosmology data

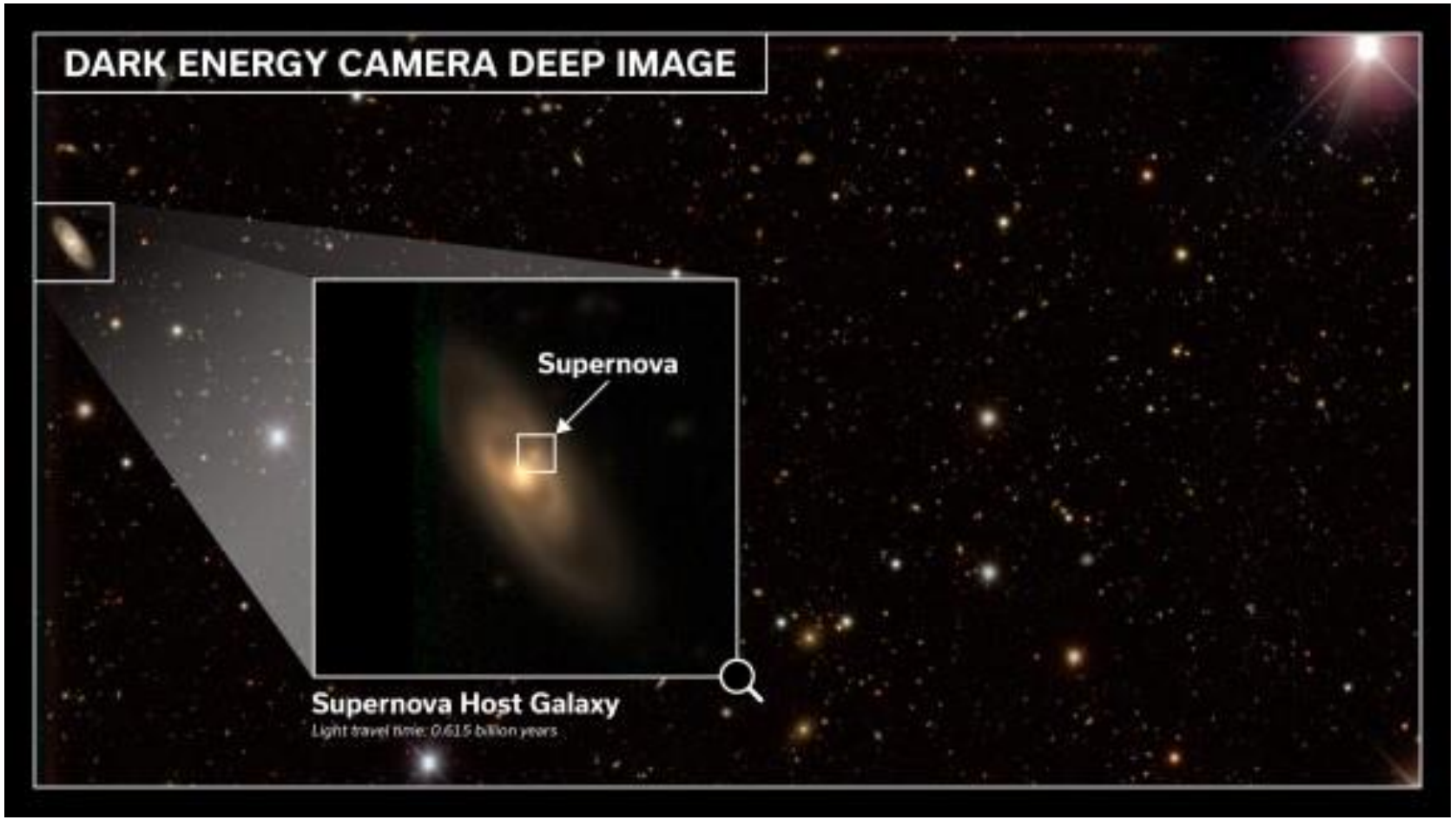




Recent results: Final Baryon Acoustic Oscillation results - a 2.1% measurement of the angular BAO Scale
"Hubble tension" - difference in results between Planck (CMB) and dark energy experiments

Dark Energy Survey (DES) presented results at the Jan. 2024 AAS mtg

Cosmology results with ~1500 new high-redshift type Ia supernovae using the full 5-year dataset. Results are consistent with a ΛCDM universe but don't rule out more complex model.



The image shows a DES supernova within the field covered by one of the individual detectors in the DECAm. The supernova exploded in a spiral galaxy with redshift = 0.04528. This is one of the nearest supernovae in the sample. Image: DES collaboration

Text & images from https://www.interactions.org/press-release/final-supernova-results-dark-energy-survey-offer-unique

Dark Energy Spectroscopic Instrument (DESI)

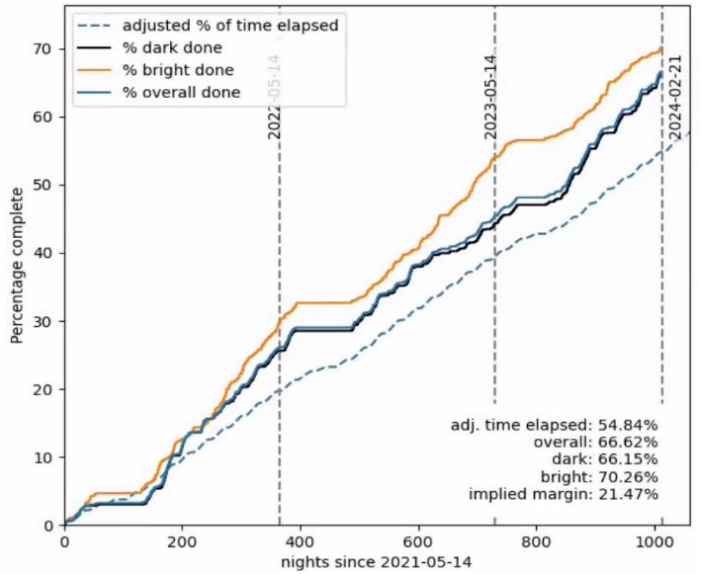
Science: World's first Stage IV DE project → Measure spectra of > 40 million galaxies to trace the universe's history at z<1.5 to study nature of dark energy, primarily using the BAO and RSD methods.

- DESI is the world's premier multi-object spectrograph w/5,000 fibers, positioned robotically
- Order of magnitude increase in results over preceding spectroscopic samples

Partnership: Primarily DOE (led by LBNL), with international & NSF-AST contributions;
Project: HEP Instrumentation, Data Management System, & Upgrades of NSF's Kitt Peak Mayall telescope (incl. MOSAIC camera).

Operations: DOE provides full support, including for Mayall operations via "lease" with NSF
→The 5-year survey started May 2021; requesting to run through mid-2028 to fill out holes in the survey for ELG's and add 3K sq deg area to overlap more w/ Rubin.

→NERSC is their computing platform – simulations, processing, analysis, serving data.



DESI is and continues to remain the most competitive instrument for wide-field spectroscopic surveys on the planet! Excellent operations and science results coming out.

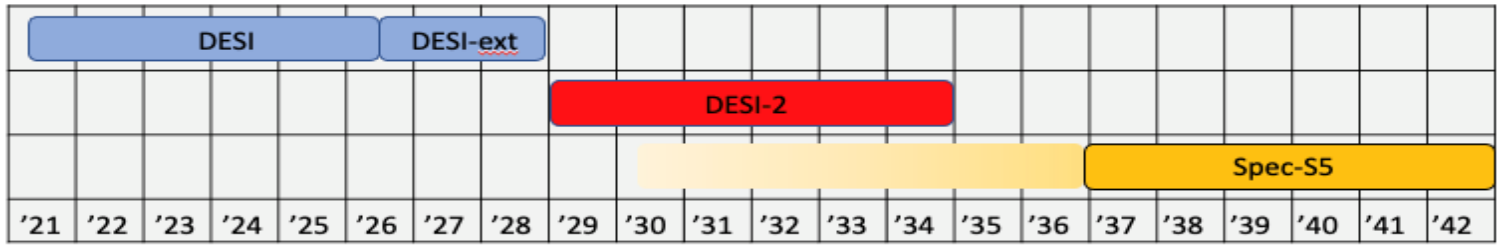
Dark Energy Spectroscopic Instrument (DESI)

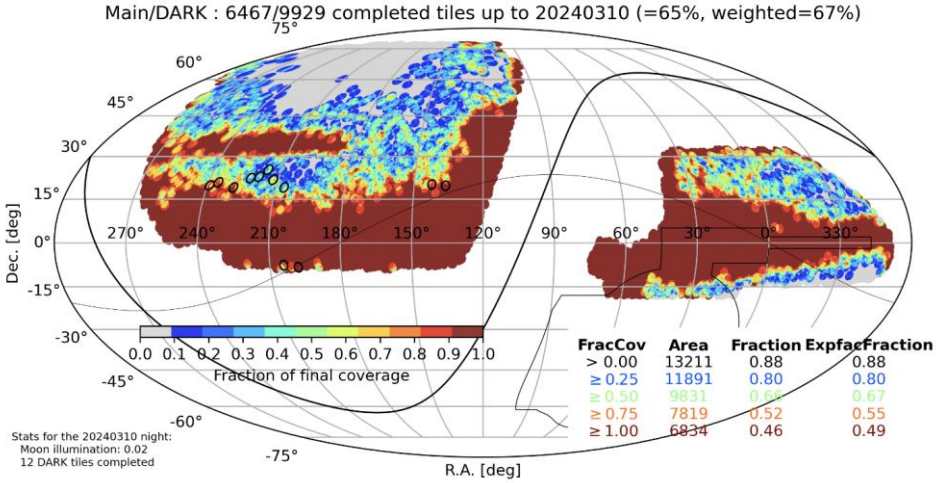
Science Status: On track to carry out key science analyses and release data on schedule.
World leading results from a very strong team (> 1200 members)!

- Jan. 2021 to Mar. 2024., DESI has published 81 refereed papers
- Year-1 analyses performed on fully blinded measurements and showed excellent robustness of the BAO to all modeling choices
  → combined theoretical, observational & modeling systematic error of 0.25% on isotropic BAO measurement
- Collaboration unblinded the Year-1 data for the Ly-a, BGS, LRG, ELG, and quasar BAO measurements
  → Cosmology results will be presented at the APS meeting on April 4th

Collaboration's future planning – see 2023 P5 recommendation

- **DESI-2**: extended operations for higher redshift (inflation physics)
  - Early dark energy and growth of structure, now in a matter-dominated phase of the universe
- **Spec-S5** – Next generation spectroscopic survey
  - Primordial physics: inflationary physics (complementary to CMB) , late-time cosmic acceleration, light relics, neutrinos masses and dark matter





As of end February 2024, DESI is running ~ 6.2 months ahead of schedule. The dark time coverage is shown in the figure above

Vera C. Rubin Observatory w/**LSSTCam** & Simonyi Survey Telescope

Science: A next-generation, ground-based facility, providing repeated imaging of faint and time-variable astronomical objects across the entire southern sky every few nights for ten years
➔ Stage IV dark energy imaging survey

NSF (AURA) & DOE (SLAC) partnership, with private, international contributions
DOE/NSF 2012 MOU for Project, Operations, Science. JOG & joint reviews

Construction/Commissioning Project:
NSF: observatory, telescope, data management, EPO, commissioning

DOE:
- **LSST Camera fabrication** completed Sept. 2021; all key performance parameters demonstrated
- **Commissioning roles -** LSST Camera assembly, test, shipment, then integration, commissioning in Chile; 9-CCD Commissioning Camera (ComCam) efforts; data quality and verification studies; overall Project roles

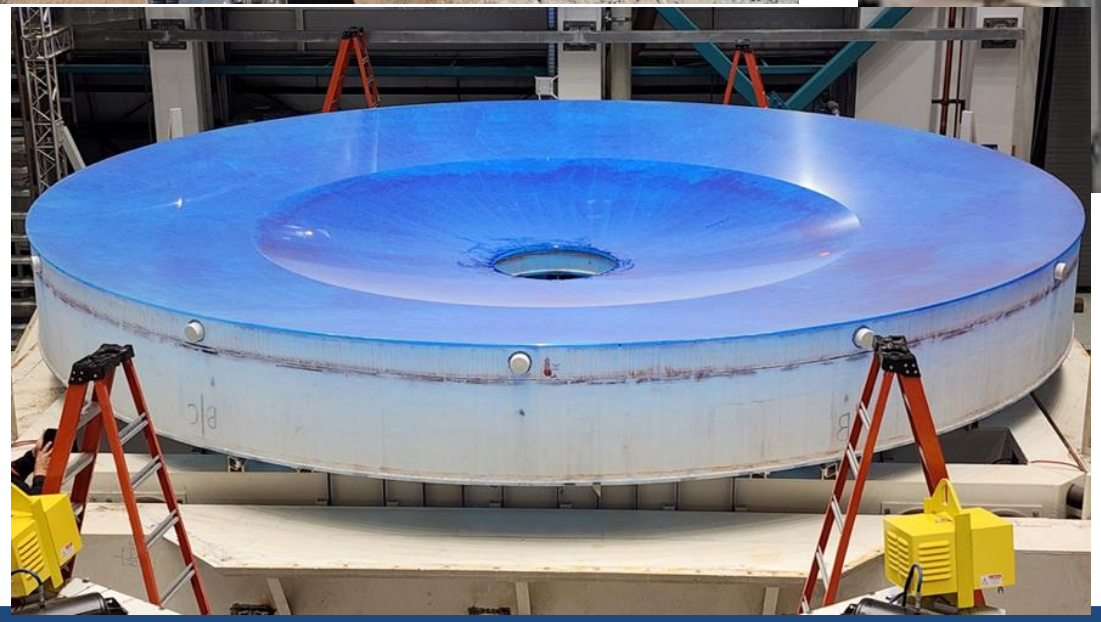
DOE's science interests are led by the Dark Energy Science Collaboration (DESC), which uses NERSC as its platform. Over 100 DESC collaborators are also part of the Rubin Commissioning team.

VERA C. RUBIN OBSERVATORY

News:
M1M3 delivered to summit!

Schedule:

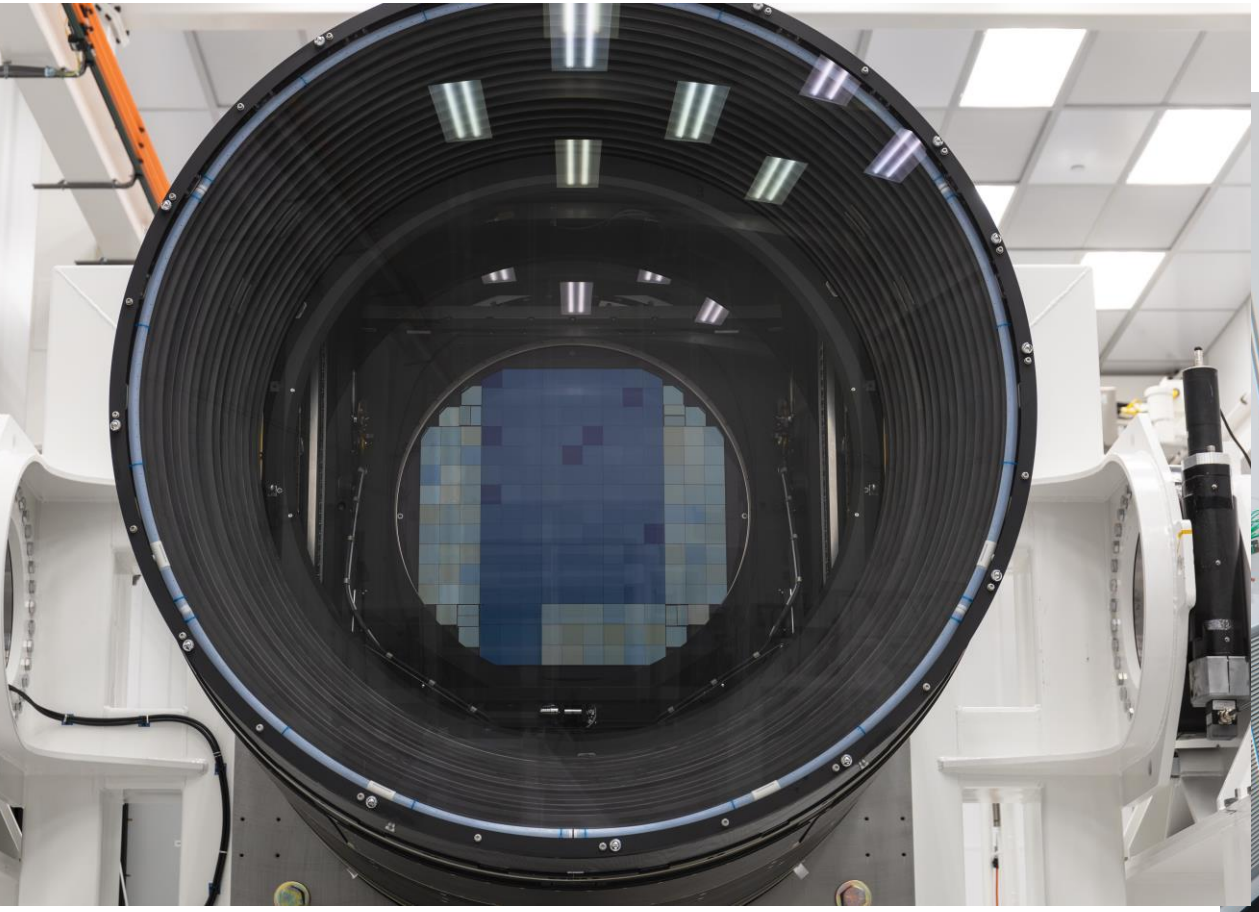
- Last part of May 2024 – LSST Camera ships to Chile
- June 2024 – ComCam back on Telescope Mount Assembly
- Sept. 2024 – Camera ready for full system integration & test
- Feb. 2025 LSSTCam on Sky (First Photon)
- Apr. 2025 – System First Light
- LSST survey starts ~ 4 to 7 months after system first light



M1M3 into Observatory

LSST Camera Integration, Test & Commissioning – at SLAC

- Fixing bumps in the road
- Packing: filters & exchange system, cryo refrigeration system
- Planning final details for shipping last part of May 2024



Rubin Observatory: Facility Operations

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

Facility Operations - DOE/NSF ~50/50 split

DOE (SLAC) is primarily responsible for the US Data Facility (USDF) , Camera maintenance and operations, and have overall operations management roles and efforts in commissioning & data quality studies.

Phases:

- Pre-operations planning & activities started 2017;
- Ten-year prime survey operations phase starts ~ late 2025
- Two-year archival consolidation process, including final LSST data release.

Planning is in full swing:

- International in-kind contributions (all US and Chilean scientists already have rights)
  - in exchange for early access to data; Data Rights Agreements are in process

- Data management, data facility planning

Carrying out Data Previews in 2024 & 2025 (DP 0.1, 0.2, 0.3 use simulated data; DESC is providing some of the simulations). DP-1 and 2 will use commissioning data.

US Data Facility (USDF)

The USDF is at the SLAC Shared Science Data Facility (S3df) in the Stanford Research Computing Facility II (SRCF)
→ Modern datacenter: 6 MW capacity
- Ultimately 80-100k cores; 30 PB/yr; 200 PB by 10 yrs

USDF Model:
- Hybrid model with hardware and initial services at SLAC.
- Rubin has a multi-site processing model → SLAC plus annual catalog processing also in the UK and France; transfers of test data demonstrated
- Rubin Science Platform (user access) in the Google Cloud

Current efforts:
- Initial testing of realistic data transfers from summit
- Delivering AuxTel data from the summit and doing prompt processing
- Preparing for multi-site processing using HSC precursor data
  - Using LHC tools for workflow (PanDA) and data mgmt (Rucio)

S3df/SRCF: SLAC Shared Science Data Facility in the Stanford Research Computing Facility

→Vera C. Rubin Observatory & the **Dark Energy Science Collaboration (DESC)**

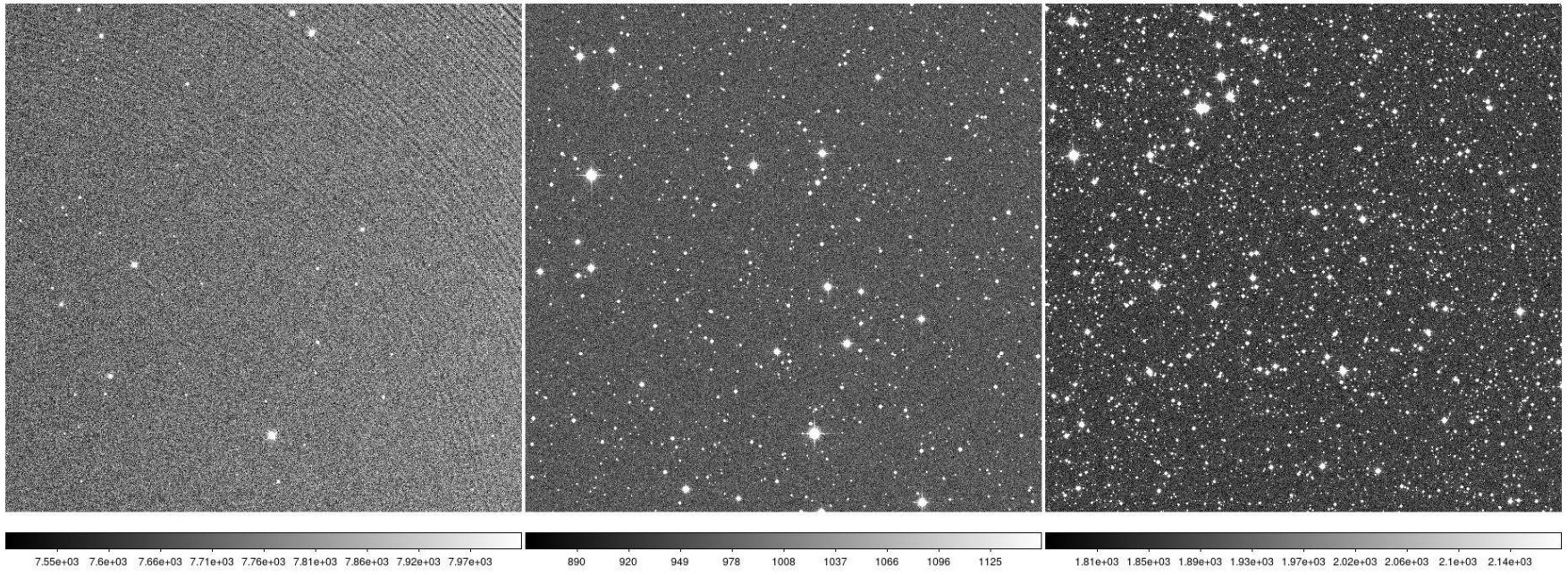
DOE's research interests are carried out by the DESC

→Preparing for data arrival with simulated and precursor data

- Fruitful collaboration between DESC and Rubin on many fronts including development of image simulation (imSim) code, being used for ComCam
- Simulations being used for Rubin Data Preview 0.X
- Many DESC collaborators (>100) also on Rubin Commissioning team
- Planning for ComCam on-sky this summer

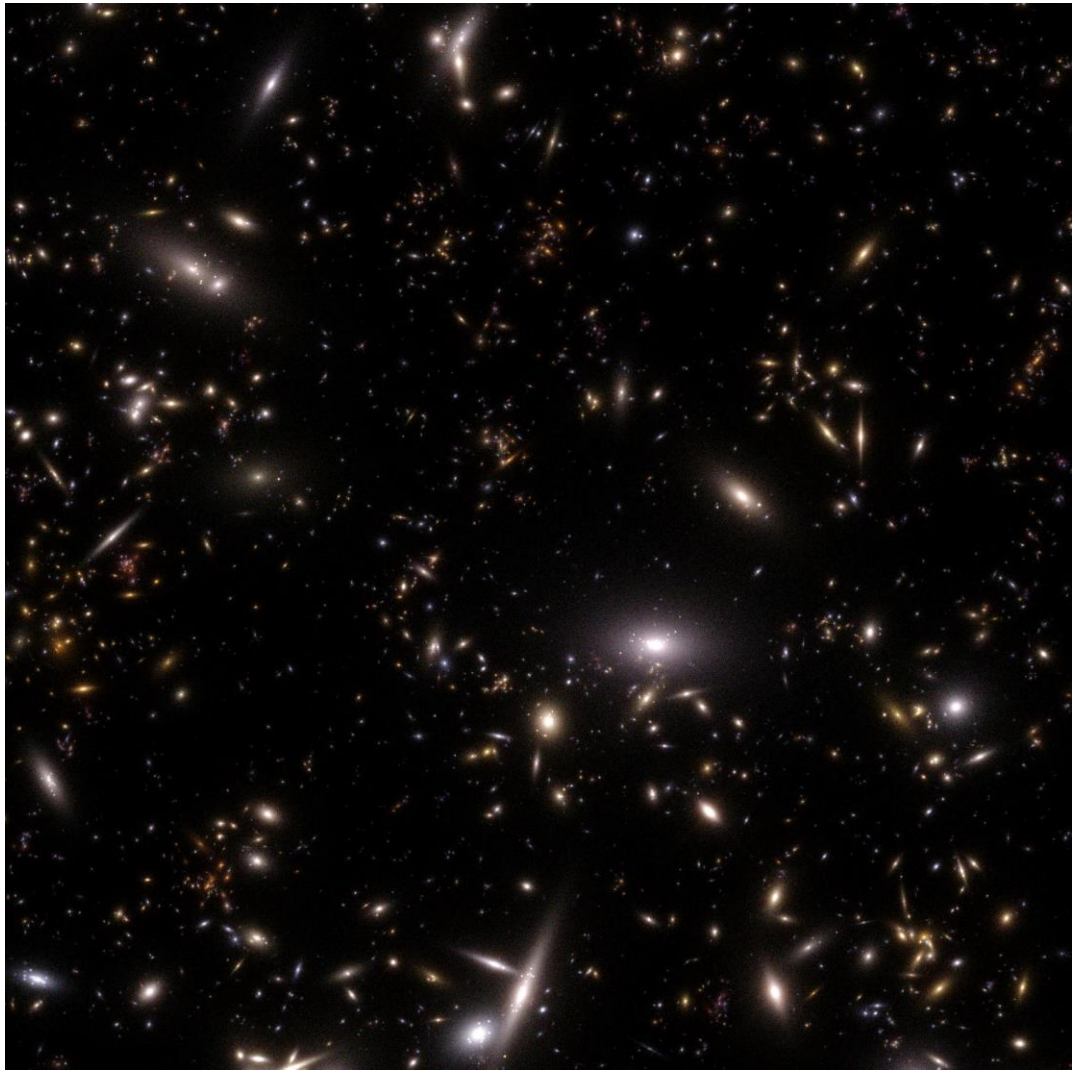
1250+ members w/250 full members; from 20+ countries.

- 87 publications overall, 30 in 2023, 8 more submitted



Worked with Nancy Grace Roman groups to do joint LSST-Roman simulations on Argonne Leadership Computing Facility (ALCF) supercomputer.

DESC – recent efforts



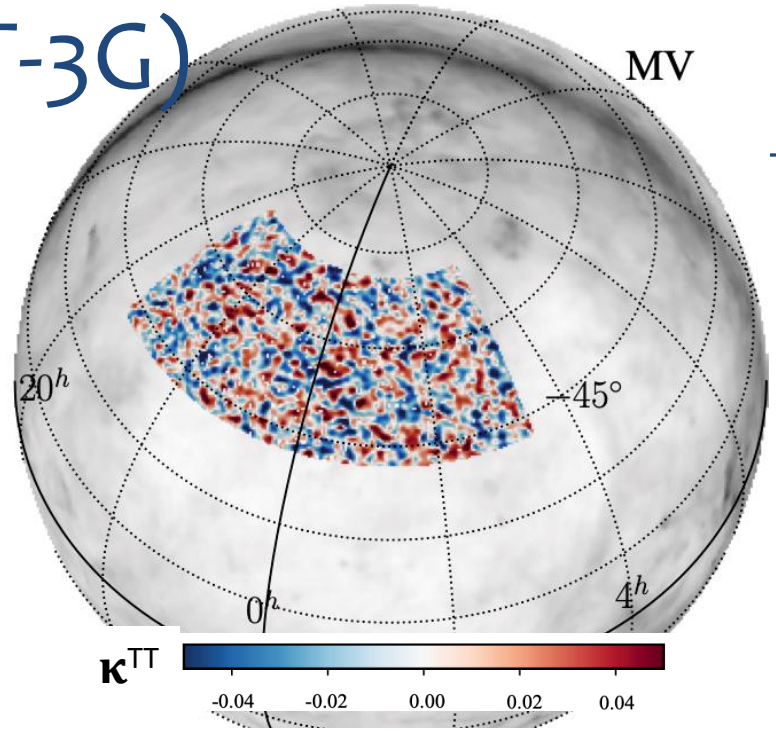
Joint pixel-level simulations of Roman & Rubin (lead: M. Troxel)

- Focus on time-domain science with **many improvements over DC2**
- Larger number of transients, new LSST cadence and transmissions, better galaxy templates and new catalogs, realistic associations of transient and host, better simulation infrastructure…
- Run on ALCF/Theta in Jan 2024 - **300 TB of wide & deep field data**

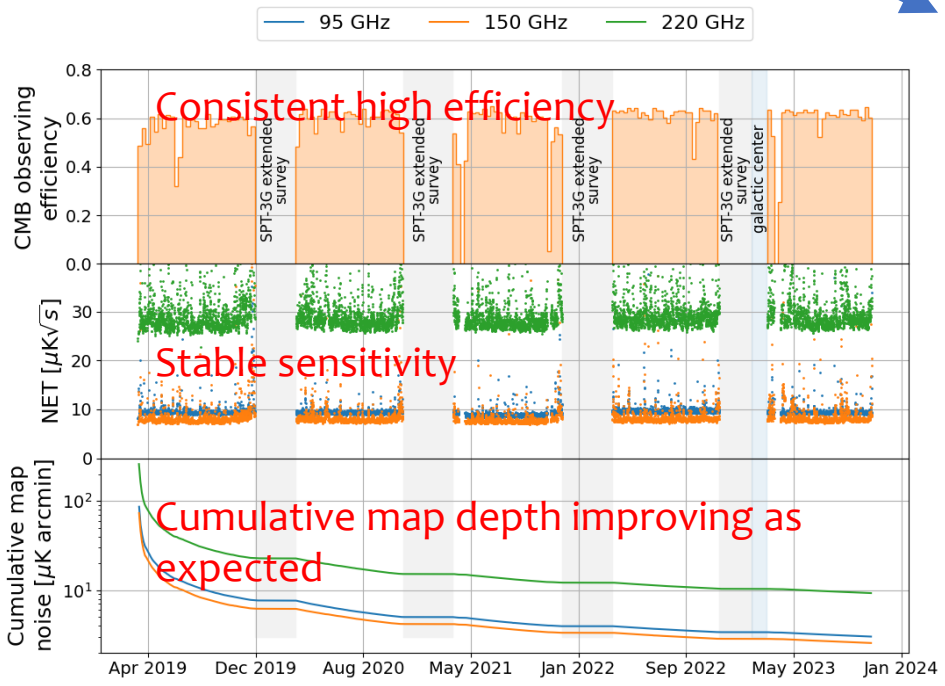
South Pole Telescope 3rd Generation (SPT-3G)

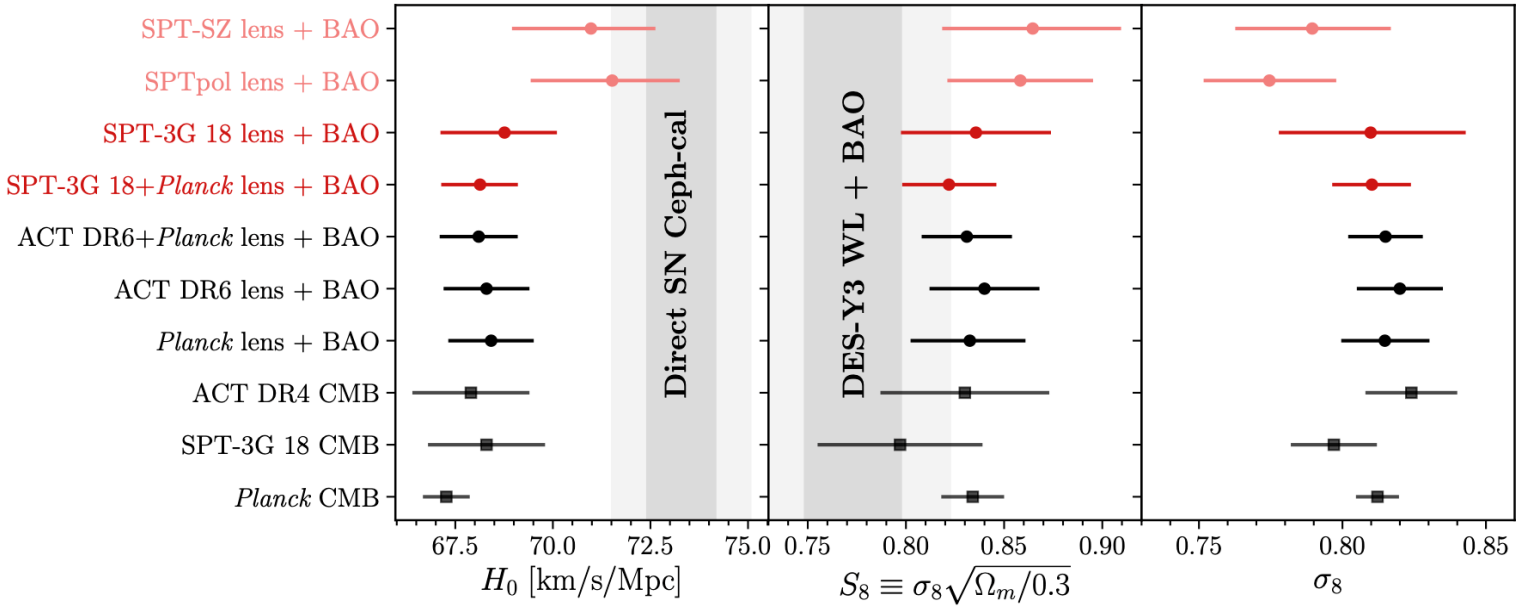
NSF & DOE partnership

- HEP supported major upgrade → fabrication of the 16,000-detector focal plane, greatly increasing sensitivity
- 5th full year of survey completed; smooth operations, high efficiency
- Cosmology results from initial 2018 SPT-3G data using joint TT, TE and EE power spectrum measurements published (Balkenhol et al. PRD, 2023)
- CMB gravitational lensing result published (Pan et al., PRD, 2023)



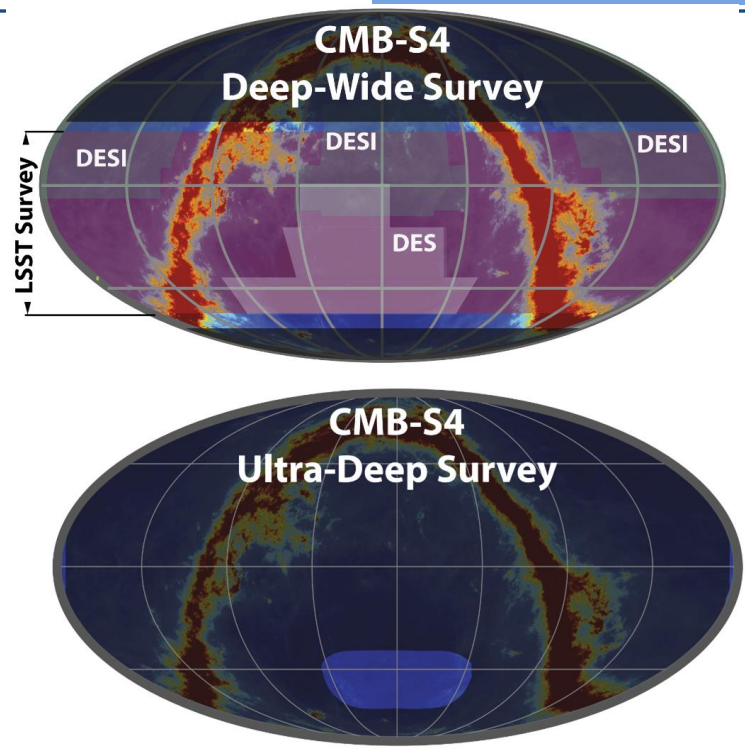
Constraints consistent with ΛCDM. H_0 & S_8 consistent with other CMB experiments; slight tension with 'local probes'





CMB-S4 (Cosmic Microwave Background Stage 4)

- 2014 P5 recommended CMB-S4 as a joint DOE/NSF
- 2015 NAS Antarctic strategic vision report recommended the CMB-S4 science case as 1 of 3 strategic investments
- CD-0 in 2019; MIE project approved FY2021
- Astro2020 recommended CMB-S4 as 2nd priority for ground-based astronomy/astrophysics
- DOE/HEP has been working with NSF to move CMB-S4 forward.
- In December 2022, the Project reported an alternative design that will address South Pole infrastructure and logistics constraints, as they understand them, and will still meet all the science goals.
  ➔This is the design that was proposed to P5.

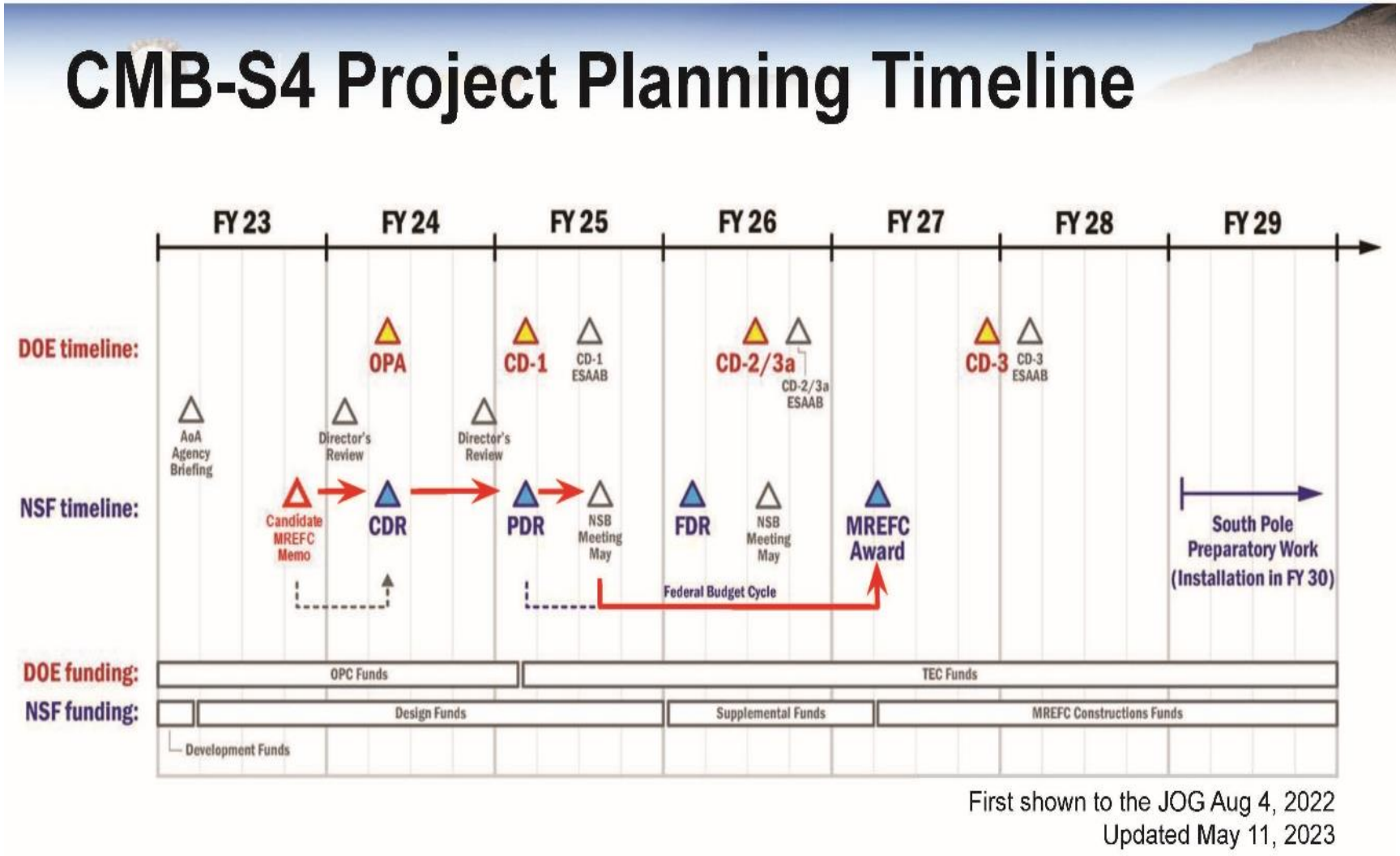


2023 P5 report: CMB-S4, with both sites, was the top recommended new project

A Director's review (charged by LBNL and U Chicago management) was held in November 2023.
The committee reported "…the project progressed well and key elements are in place including a well-defined conceptual design developed through a rigorous process, a well-developed and effectively operating management structure, and a solid and well-documented conceptual-design-level project plan"

DOE does not want to get too far ahead of NSF.

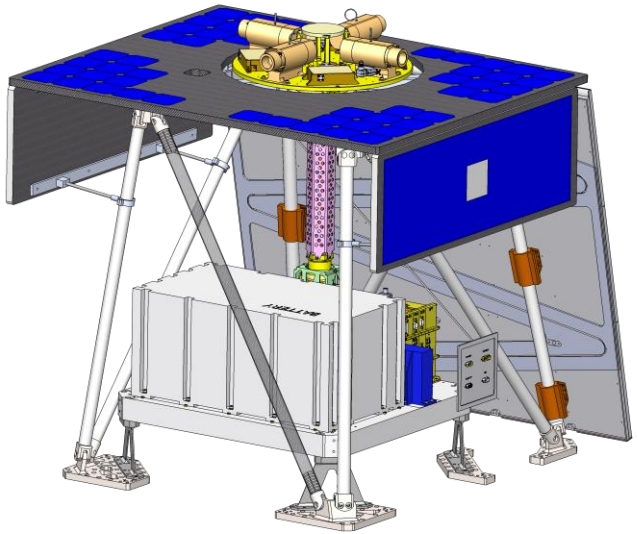
CMB-S4 – Project's technically limited timeline



LuSEE-Night
→ Pathfinder to the Dark Ages

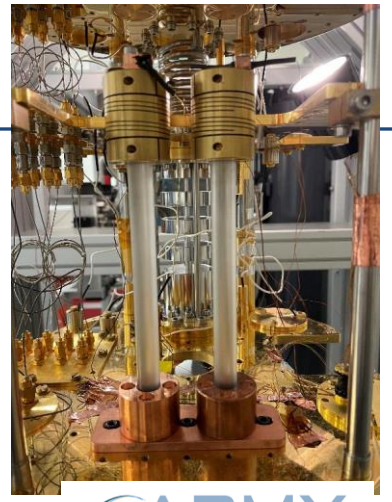
Pathfinder mission to place the most sensitive constraints to date on the **Dark Ages signal** & potentially discover the Dark Ages signal.

- Capability to measure the radio environment and observe the long-wavelength radio signal on the lunar farside.



DOE (BNL) & NASA (UCB/SSL) partnership – a CLPS mission
- Delivery to Firefly Aerospace in early 2025
- Launch December 2025

Direct Detection Dark Matter Generation 2 (DM-G2)



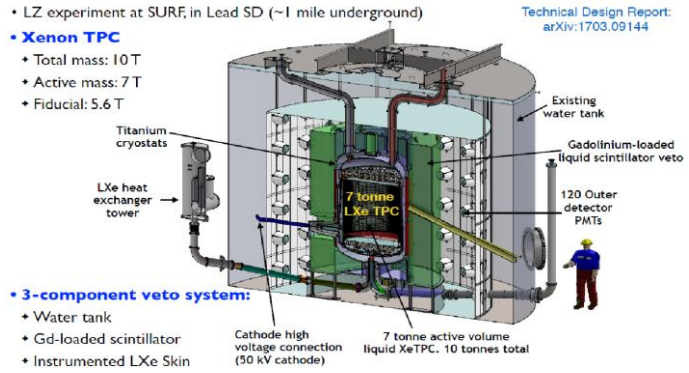
The 2014 P5 recommended a DM-G2 suite using a variety of methods and technologies to search for dark matter particles

ADMX-G2 operating since Feb. 2017 at U.Wash

- Search for QCD axions, Ten-trillionth of the mass of an electron, using a haloscope experiment, in which an axion would convert to a photon in the presence of a strong magnetic field

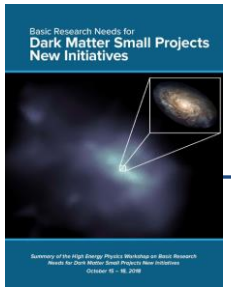
LZ operating since Dec. 2021 underground at SURF in S. Dakota

- Search for WIMPs 10-1000 GeV mass using Time Projection Chamber with 7 tons liquid Xenon



SuperCDMS SNOLAB underground in Sudbury, Canada

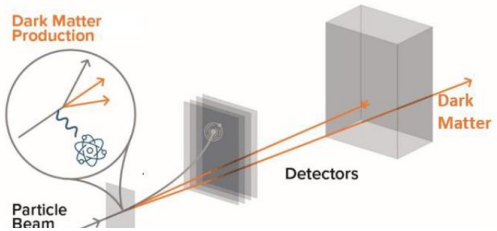
- Installation/testing now; Data-taking starts in 2025
- Search for WIMPs 1-10 GeV mass using cryogenic solid-state crystal germanium and silicon detectors



Dark Matter New Initiatives (DMNI)

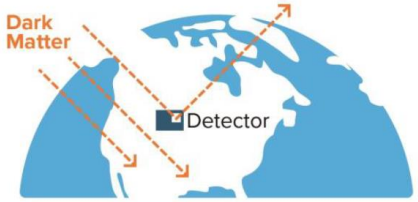
PRD 1: Create and detect dark matter particles below the proton mass and associated forces, leveraging DOE accelerators that produce beams of energetic particles.

Create & Detect Dark Matter at Accelerators



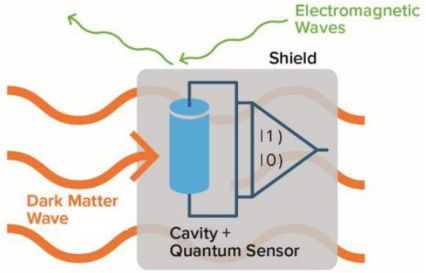
PRD 2: Detect individual galactic dark matter particles below the proton mass through interactions with advanced, ultra-sensitive detectors.

Detect Galactic Dark Matter Underground



PRD 3: Detect galactic dark matter waves using advanced, ultra-sensitive detectors with emphasis on the strongly motivated QCD axion. [1]

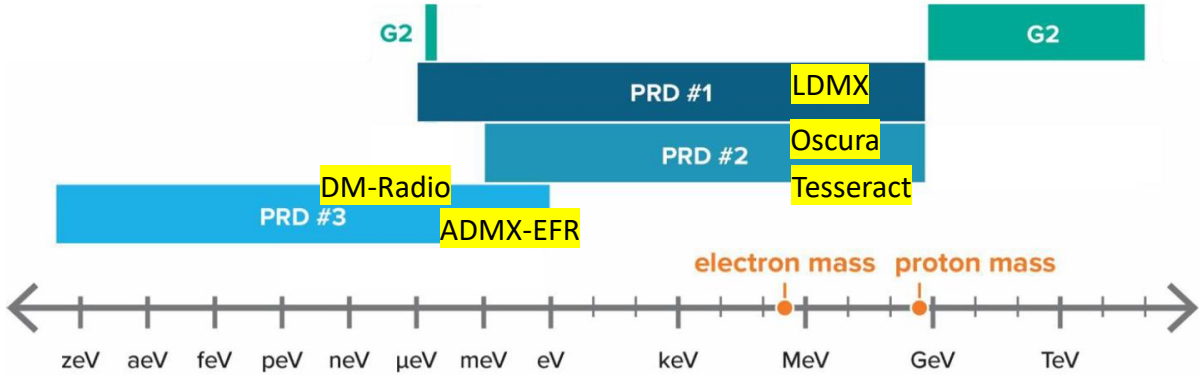
Detect Wave Dark Matter in the Laboratory



After the 2014 P5 →

- Theoretical advances from fundamental physics, cosmology and data anomalies has broadened the types, mass, areas of phase space, and paradigms for DM searches.
- Technology advancements allow new experimental methods.

➔ These advances enable DM searches in new areas of phase space using small projects.

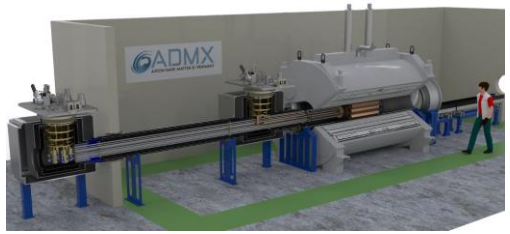


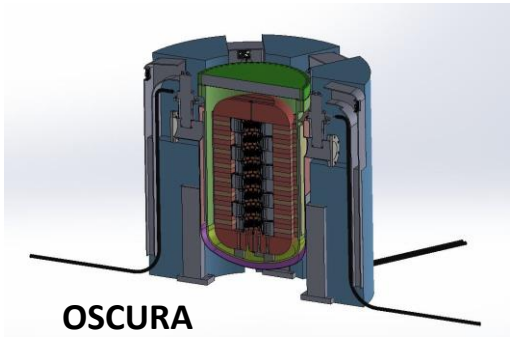
Dark Matter New Initiatives (DMNI)

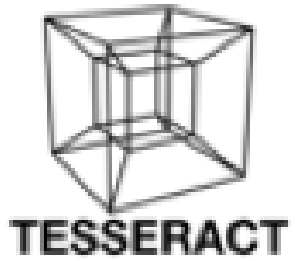
5 concepts are developed – final technology R&D, project execution plans

Concept	DM type	Mass range
ADMX-EFR	Axions	9-17 μeV
DM-Radio	Axions	<μeV
LDMX	Hidden sector	10-300 MeV
OSCURA	WIMPs	1MeV-1GeV
TESSERACT	WIMPs	>10 MeV

- By 2025/2026, all 5 concepts expect to have plans at the maturity needed to be considered to move to a project start.







U.S. DEPARTMENT OF ENERGY | Office of Science

Summary

DEI & Outreach

Many efforts are going on within SC overall and HEP.

Some examples from HEP:
HEP program managers have been attending a variety of conferences and a more diverse set of institutions than have historically been supported by HEP for particle physics research. This includes outreach visits to HBCU's and small institutions to spread the word about new focused funding opportunities and encourage these institutions to build STEM infrastructure.

- Funding for Accelerated, Inclusive Research (FAIR)
- Reaching a New Energy Sciences Workforce (RENEW)
- Workforce Development for Teachers and Scientists (WDTS)
- Science Undergraduate Laboratory Internships (SULI)

- **RENEW (FY24 Request $11.5M):** Expands targeted efforts to increase participation and retention of individuals from underrepresented groups in SC research activities
- **FAIR (FY24 Request $4.0M):** Improve capability of HBCUs and MSIs to perform and propose competitive research and build beneficial relationships between these institutions and DOE national laboratories and facilities.

DOE - Energy Sustainability

- All elements of DOE are required to minimize waste and pollution and work towards ensuring environmental sustainability.
- All site activities are audited every three years to conform to obligations in accordance with the Office of Environment, Health, Safety and Security (EHSS) & conform to the International Organization for Standardization's (ISO) 14001.
- DOE elements must also address environmental justice. Specifically, DOE elements must: (1) ensure disadvantaged communities and adverse impacts on those communities that may be exacerbated by DOE operations are identified and documented, and (2) develop and implement programs to secure environmental justice for disadvantaged communities that have been historically marginalized and overburdened by climate-related impacts.

2022 DOE Sustainability Plan

- 100 percent carbon pollution-free electricity
- 100 percent zero-emission vehicle fleet by 2027
- Net-zero emission buildings by 2045
- Reducing waste and pollution by 50% by FY 20205 and 75% by FY 2030
- Sustainable procurement
- Climate- and sustainability-focused workforce
- Incorporating environmental justice

HEP ➔ Summary & Future Planning

- HEP continues to carry out the 2014 P5 strategic plan

- **FY 2024+ Developing a plan forward aligned with the 2023 P5 strategic plan**
  - Incorporate guidance from the 2023 International Benchmarking study

  - First Look will be at the May 9-10 HEPAP meeting
  - Likely to be FY2025+ before any decisions are incorporated into the HEP program plan.

U.S. DEPARTMENT OF
ENERGY | Office of Science