Office of High-Energy Physics (HEP) Cosmic Frontier Subprogram report to the CAA

Kathy Turner
January 16, 2026

Cosmic Frontier team
Kathy Turner (kathy.turner@science.doe.gov)
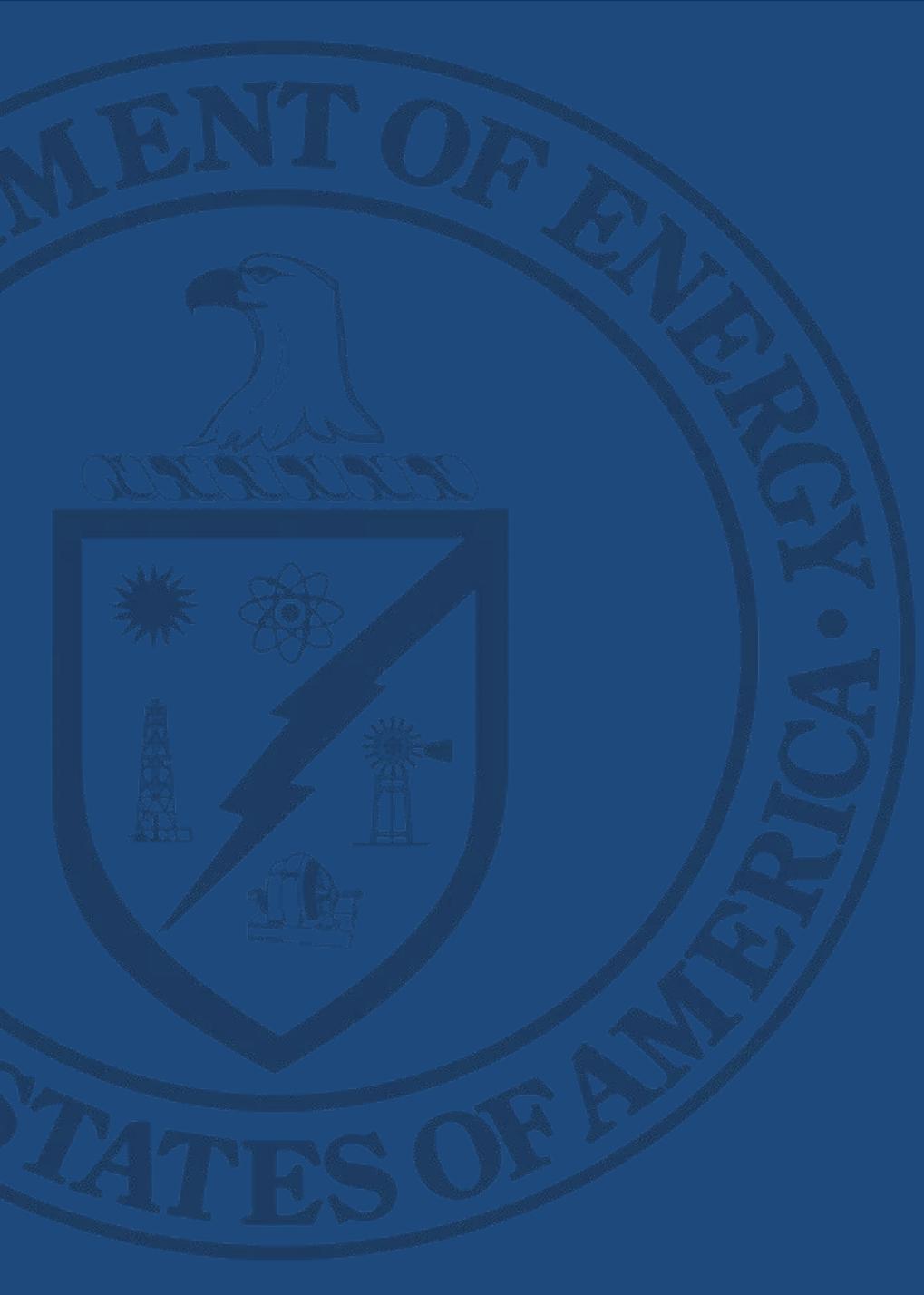Bryan J. Field (bryan.field@science.doe.gov)
Manuel Bautista (manuel.bautista@science.doe.gov)

U.S. DEPARTMENT of ENERGY | Office of Science

- **Intro**
- **Budget**
- **CF program**

Mission Agency: DOE → SC → HEP

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

- Office of Science (SC): deliver the scientific discoveries and major scientific tools that transform our understanding of nature and advance the energy, economic, and national security of the U.S.

- **Office of High Energy Physics (HEP): <u>understand the universe at the most fundamental level</u>:**
  - Discover the elementary constituents of matter and energy
  - Probe the interactions between them
  - Explore the basic nature of space and time

<u>HEP is carried out along 3 Science Frontiers</u> (**Energy, Cosmic, Intensity**) Advancements at all 3 frontiers are needed to achieve the long-term goals of the field. It is primarily a Particle Accelerator based program.
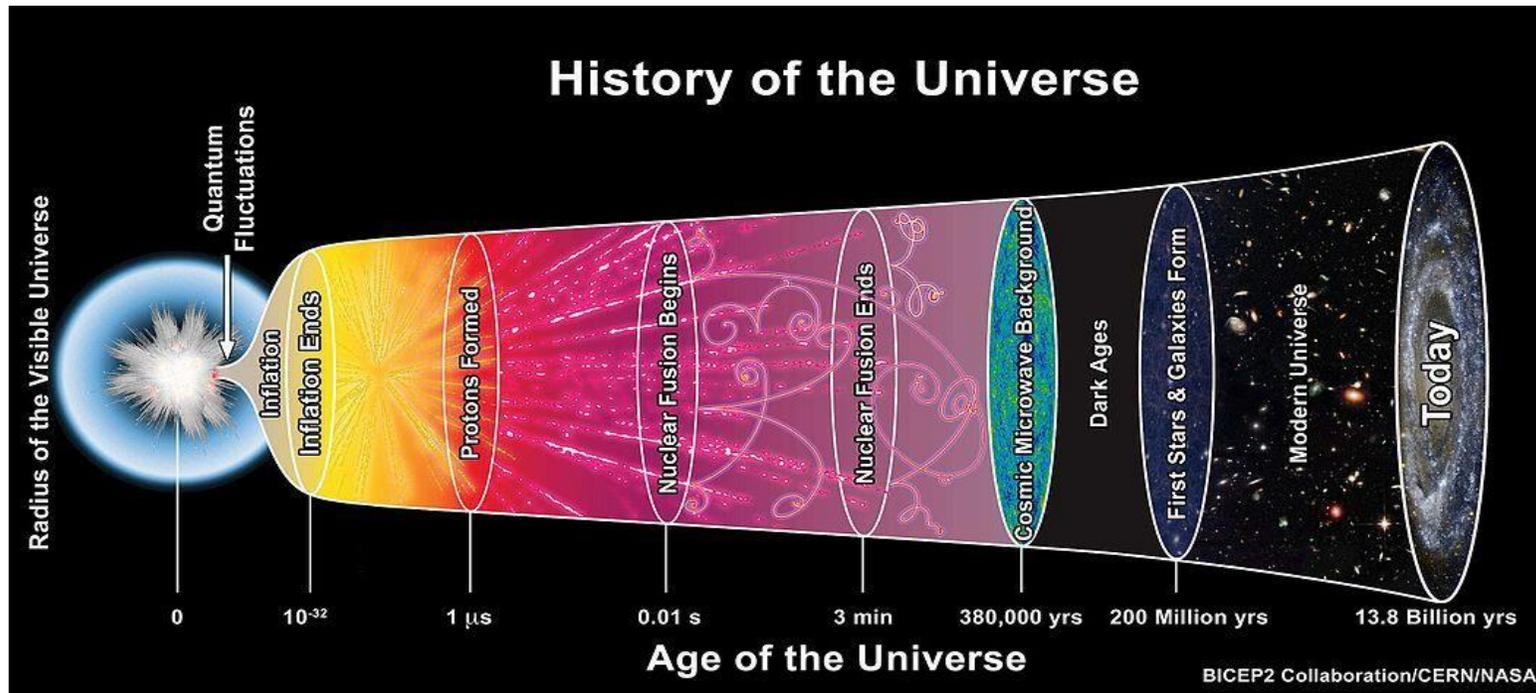- Major efforts in **Theory, Detector R&D, AI/ML, Quantum, Accelerator R&D**, etc.

Atoms 4.6%
Dark Matter 23%
Dark Energy 72%
TODAY
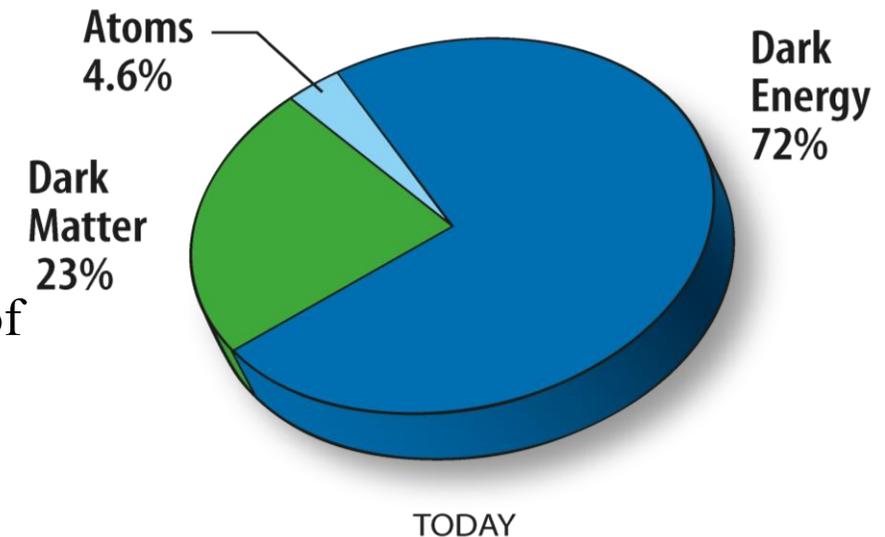
HEP Cosmic Frontier

Cosmic Frontier has become an important area for discovery.

Experiments use naturally occurring data to provide additional input to the Standard Model picture:
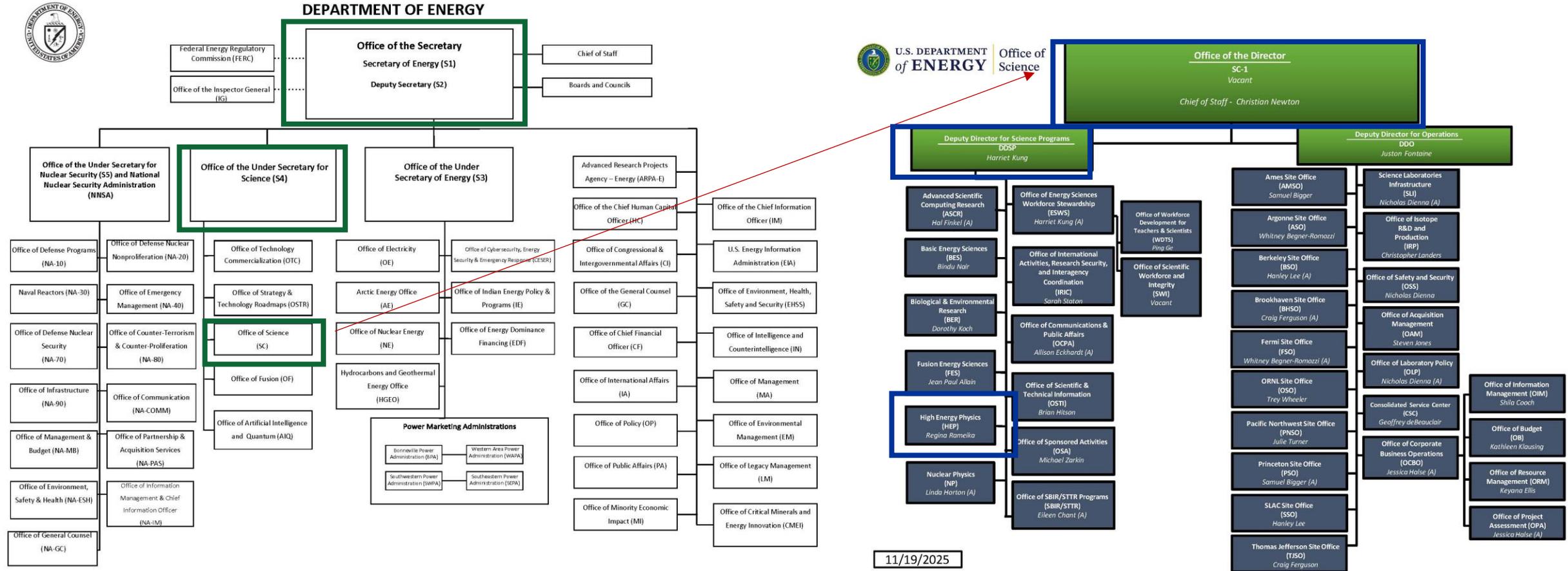Cosmic Acceleration (Dark Energy, Inflation), Dark Ages, search for Dark Matter particles, Neutrino properties, New Physics (e.g., relic particles, etc.)

History of the Universe — BICEP2 Collaboration/CERN/NASA

Cosmic Frontier:
- Have extensive use of AI; will continue growing.
- Projects/Experiments enhanced by other HEP efforts in Theory, Detector R&D, Quantum, AI/ML plus
  - Other SC efforts
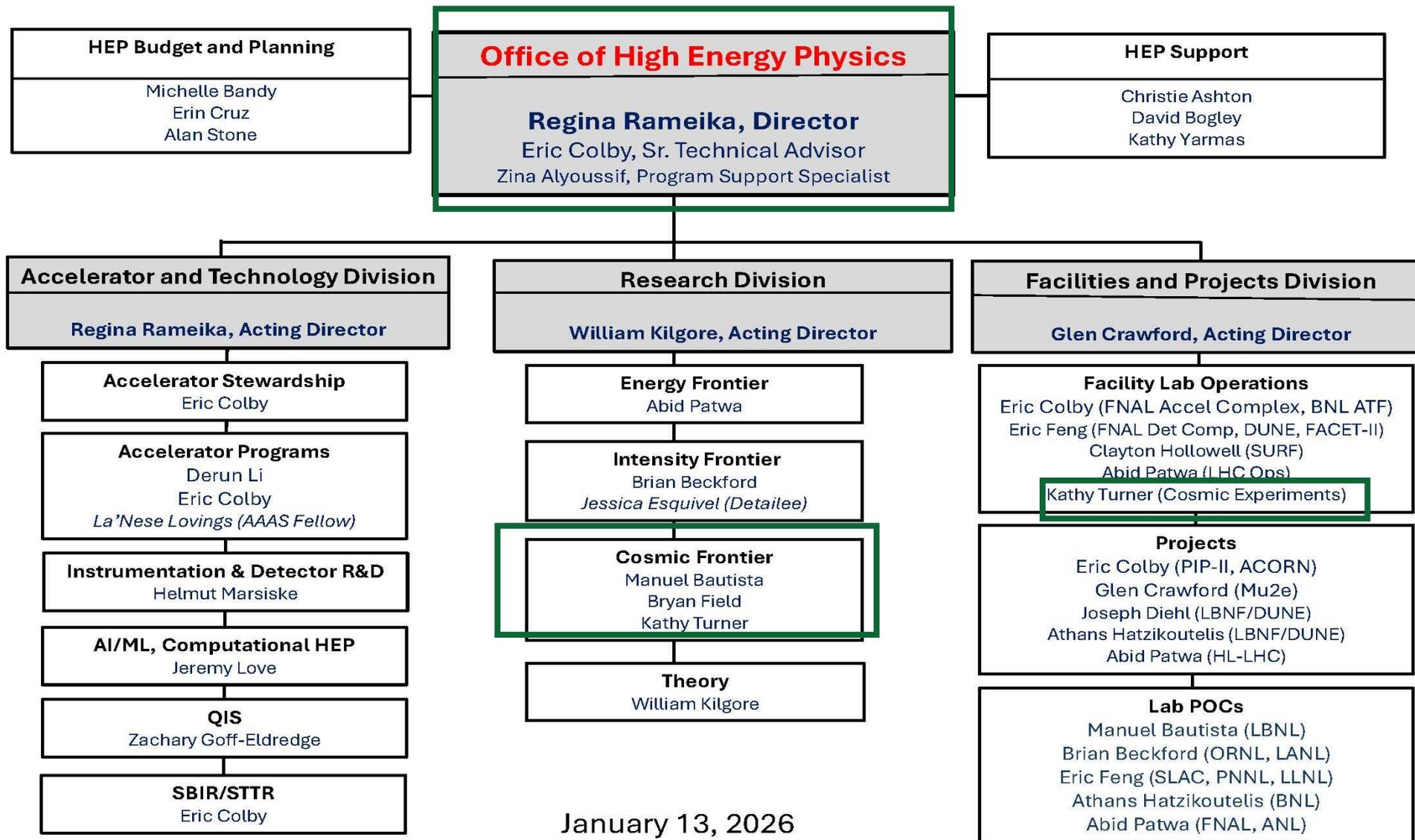 - Interagency & international partnerships

DOE → SC → HEP Organization

DOE → SC → HEP Organization

HEP Budget and Planning

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Regina Rameika, Acting Director

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Accelerator Programs
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AI/ML, Computational HEP
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QIS
Zachary Goff-Eldredge

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Energy Frontier
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Cosmic Frontier
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Theory
William Kilgore

Facilities and Projects Division

Glen Crawford, Acting Director

Facility Lab Operations
Eric Colby (FNAL Accel Complex, BNL ATF)
Eric Feng (FNAL Det Comp, DUNE, FACET-II)
Clayton Hollowell (SURF)
Abid Patwa (LHC Ops)
Kathy Turner (Cosmic Experiments)

Projects
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Glen Crawford (Mu2e)
Joseph Diehl (LBNF/DUNE)
Athans Hatzikoutelis (LBNF/DUNE)
Abid Patwa (HL-LHC)

Lab POCs
Manuel Bautista (LBNL)
Brian Beckford (ORNL, LANL)
Eric Feng (SLAC, PNNL, LLNL)
Athans Hatzikoutelis (BNL)
Abid Patwa (FNAL, ANL)

January 13, 2026

DOE → 17 National Labs (10 are Office of Science Labs)

The National labs comprise a preeminent federal research system, providing the Nation with strategic scientific and technological capabilities.

→Conduct research & development that addresses DOE's core missions in energy, science, national security, and environmental stewardship.

- Tackle the critical scientific challenges of our time

- Possess unique instruments and facilities, many of which are found nowhere else in the world

- Address large scale, complex R&D challenges with a multidisciplinary approach

OFFICE OF SCIENCE BY THE NUMBERS

Delivering scientific discoveries and major scientific tools to transform our understanding of nature and advance the energy, economic, and national security of the United States

FY25

6 CORE SCIENCE PROGRAMS
- Advanced Scientific Computing Research
- Basic Energy Sciences
- Biological and Environmental Research
- Fusion Energy Sciences
- High Energy Physics
- Nuclear Physics

2 ENGINEERING AND TECHNOLOGY OFFICES
- Isotope Research and Development and Production
- Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR)

5 NATIONAL QUANTUM INFORMATION SCIENCE RESEARCH CENTERS

ACROSS ITS 10 NATIONAL LABS, OFFICE OF SCIENCE MAINTAINS APPROXIMATELY

24 MILLION SQUARE FEET OF SPACE

1,600 BUILDINGS | **38,000 ACRES OF LAND OWNED**

SUPPORTS RESEARCH SPANNING

17 DOE NATIONAL LABS

50 STATES, PUERTO RICO, AND WASHINGTON, D.C.

STEWARDS 10 DOE NATIONAL LABORATORIES

3 World-Leading Supercomputers

ESTIMATED RESEARCHERS SUPPORTED
- 10,100 Permanent PhDs
- 3,100 Postdoctoral Associates
- 4,800 Graduate Students
- 9,900 Other Scientific Personnel

NEARLY **43,000 USERS AT 28 OFFICE OF SCIENCE FACILITIES**

10 SITE OFFICES
1 CONSOLIDATED SERVICE CENTER

OVER **120 NOBEL PRIZES**

>300 UNIVERSITIES AND HIGHER-LEARNING INSTITUTIONS

$8.2 BILLION OVERALL OFFICE OF SCIENCE BUDGET | **$991 MILLION USER FACILITY CONSTRUCTION** | **$261 MILLION SCIENCE LABORATORIES INFRASTRUCTURE**

Timeline of FY 2026 HEP Budget Headlines

→ Currently in a Continuing Resolution through Jan. 30, 2026.

FY25 Enacted	FY26 Request	FY25 Enacted	FY25 Enacted	FY26 Markup	FY26 Request	FY26 Enacted	FY26 Markup

FY25 Enacted

15 Mar 2025

H.R. 10545, Full-Year Continuing Appropriations and Extensions Act, 2025, signed into law.

Continues at FY 2024 funding levels

1200M HEP + 27M ARDAP

FY26 Request

2 May 2025

White House unveiled its FY 2026 "skinny" budget proposal, which included a 23% reduction in non-defense spending and 13% increase in defense spending.

No funding details released

FY25 Enacted

Jul 2025

As part of the balancing across SC programs, HEP's budget was increased by 24.57M targeting facilities and AI

1224.57M HEP + 27M ARDAP

FY25 Enacted

4 Jul 2025

The One, Big, Beautiful Bill Act of 2025 included $150 million specifically for the Department of Energy (DOE) Office of Science to develop the American Science Cloud.

1234.57M HEP + 27M ARDAP

FY26 Markup

23 Jul 2025

House Appropriations Subcommittee on Energy and Water Development, and Related Agencies released a summary for the FY 2026 House Mark.

1229.84M HEP

FY26 Request

Jul 2025

Full details of the FY 2026 PBR released. Strong support for Projects; Facilities; AI/ML & QIS. Support for other Research activities to focus on high-profile research topics and early research results; key contributions and critical U.S. commitments to experiments & projects

1113M HEP

FY26 Enacted

12 Nov 2025

H.R.5371 - Continuing Appropriations, Agriculture, Legislative Branch, Military Construction and Veterans Affairs, and Extensions Act, 2026, signed into law.

Continues at FY 2025 funding levels through 30 Jan 2026

FY26 Markup

24 Nov 2025

Senate Appropriations Subcommittee on Energy and Water Development released a summary for the FY 2026 Senate Mark.

1253M HEP

HEP Budget History 2013 to Present
→ **Currently in a Continuing Resolution through Jan. 30, 2026.**
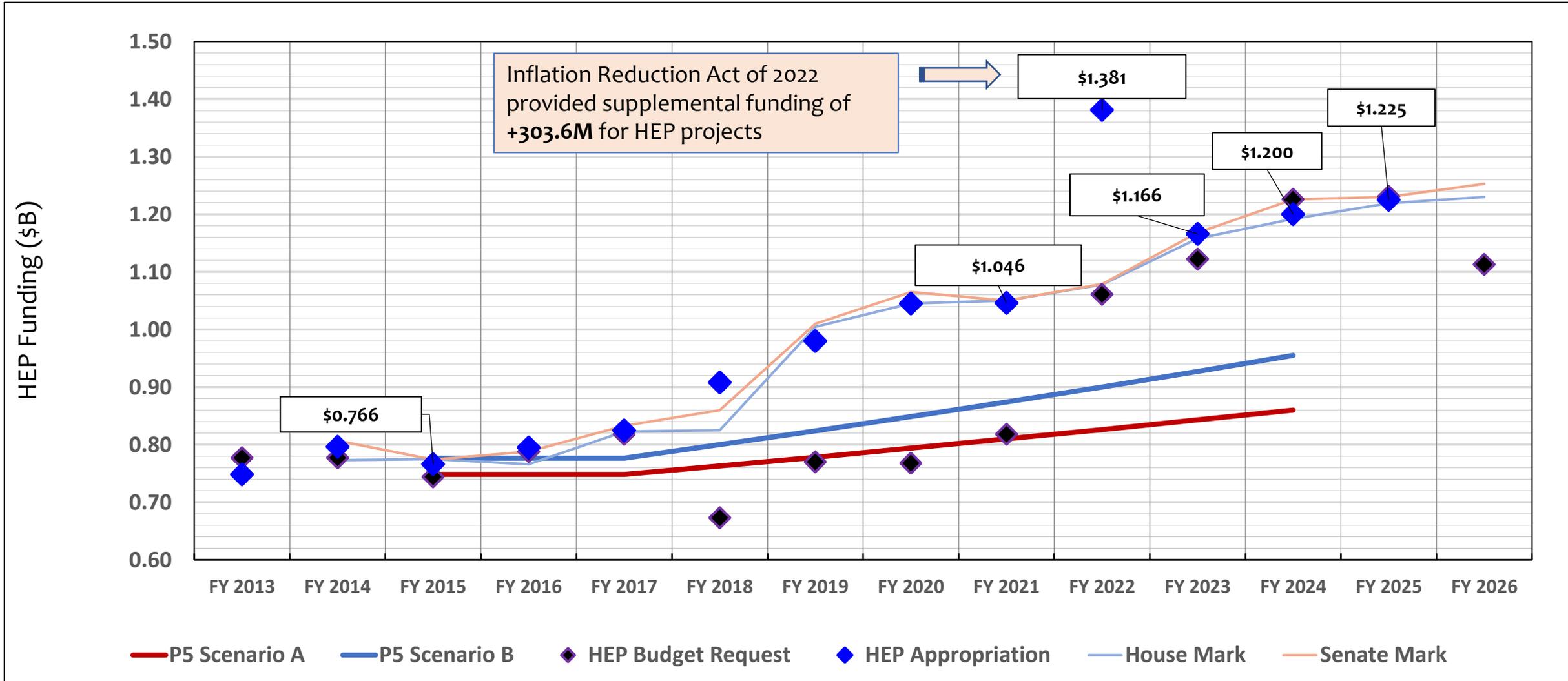
HEP FY 2026 President's Request Highlights
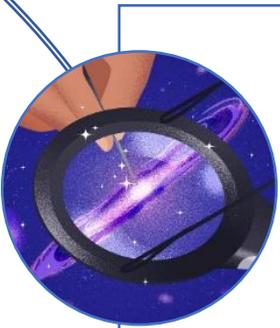
Research $302.2M (-$131.4M, -30.3% from FY 2025 Enacted*)

- +$ 11.8M for AI/ML
- +$ 6.5M for QIS
- Microelectronics continues at the FY 2025 Enacted Level
- -$149.6M for other Research activities → Focus support on high-profile research topics and early research results; key contributions and critical U.S. commitments to experiments & projects; University research

Facilities Operations $407.3M (+$13.4M, +3.0% from FY 2025 Enacted*)

- +$ 10.0M for Fermilab Accelerator Complex
- +$ 3.0M for SURF
- +$ 3.0M for FACET-II
- - $ 2.6M across Energy, Intensity, and Cosmic Frontiers, ATF, BELLA, Other Accelerator and Detector Test Facilities, and BeamNetUS

Projects $403.4M (-$20.8M, -4.9% from FY 2025 Enacted)

- Continued support for LBNF/DUNE's five subprojects and ACORN.
- -$11.0M for the PIP-II, per the planned profile
- -$ 5.3M for the ATLAS and CMS Detector Upgrades, per their planned profiles
- -$ 4.5M for the CMB-S4 MIE project

Starting in FY 2026, the ARDAP Program activities were merged into the HEP Program request. The delta is comparable adjusted to include ARDAP portion of funds in FY25 Enacted for an accurate comparison.

Budget Details

		FY23 Actual	FY24 Actual	FY25 Actual	FY26 Request
Cosmic	Research (includes Core, AI/ML, Future Project R&D)	52,417	54,201	*58,261*	27,712
Cosmic	Facility/Operations	58,760	58,021	*55,495*	54,900
Cosmic	Projects (MIE)	1,000	4,500	*3,375*	-
HEP	Research, Fac/Ops	821,787	791,774	812,708	709,436
HEP	Projects (MIE & Construction)	355,000	421,200	423,075	403,400
HEP	Total	1,176,787	1,212,974	1,235,783	1,112,836
SC	**Total**	**8,100,000**	**8,240,000**	**8,240,000**	**7,092,000**

FY 2025
- Final Appropriation with a full-year CR signed in March 2025
- $10M for AI/ML appropriated in a July 2025 supplemental One Big Beautiful Bill (not shown above)

FY 2026
- Starting in FY 2026, funding for ARDAP (Accelerator R&D and Production) is merged into HEP. The FY23-25 HEP columns in the above table include the ARDAP funding for an accurate comparison

HEP Budget – Detailed History
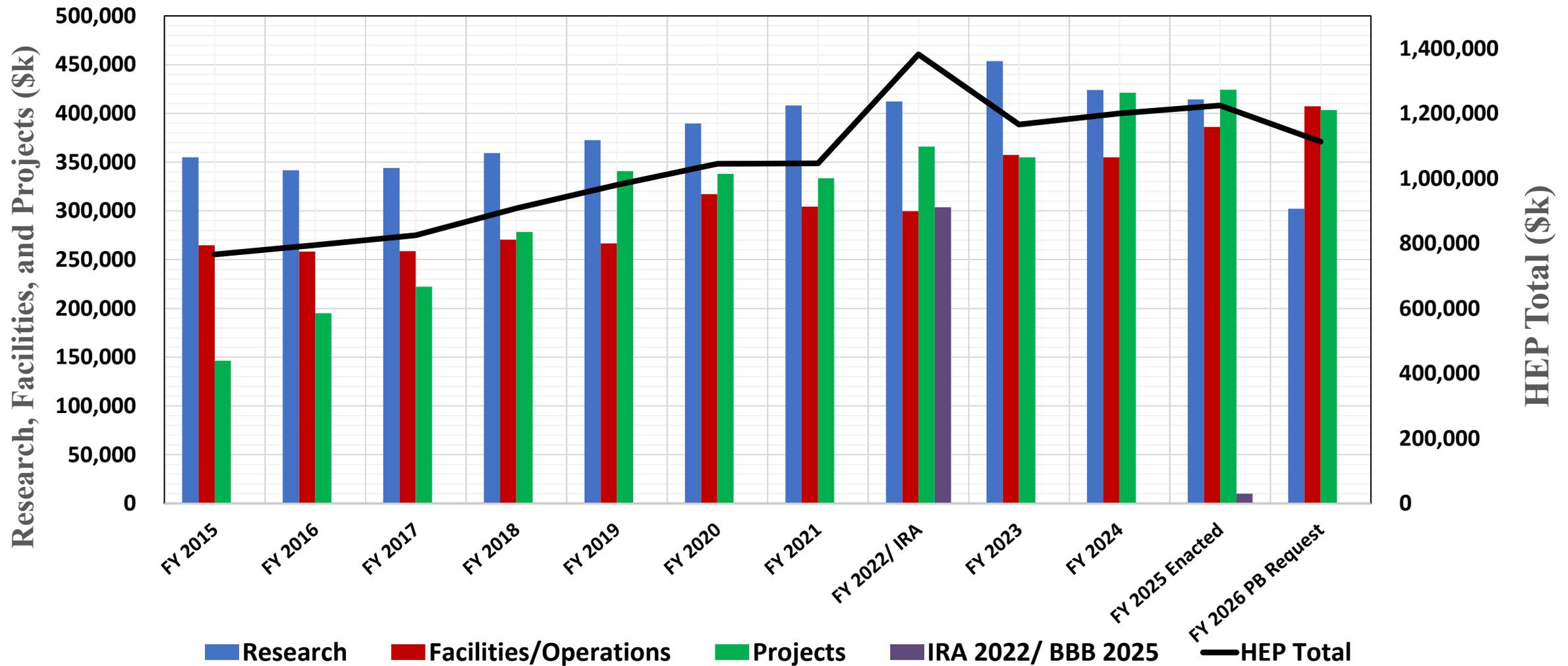
- Inflation Reduction Act (IRA) of 2022 funds supported Projects only
- Big Beautiful Bill Act of 2025 funds supported AI/ML Research only – added $10M to HEP

Office of Science and Higher-Level Initiatives

SC Research Initiatives provide focus on technical areas of strategic importance to:

- Support research in new cutting-edge technologies
- Develop new technologies into mature systems for future experiments
- Provide new capabilities for breakthrough basic science

Microelectronics

Quantum
Information
Science

AI/ML

HEP Appropriations (Millions)
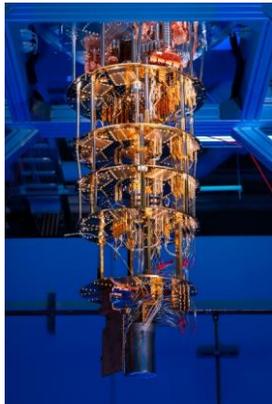
Within HEP ➔ Initiatives emphasize strategic topics which can benefit HEP science, and where HEP expertise can uniquely benefit the broader initiative ecosystem.

HEP – Executing the Mission

Mission-driven: Develop and support a **specific portfolio of projects** to make big leaps in scientific capabilities and results, aligned with our science drivers.

-- **Funding priority** is to support construction, operations & research on these particular projects

- Design, Construct & Operate next-generation, state of the art instrumentation and facilities
- Make critical use of our infrastructure and expertise
- Tradition of large scientific collaborations to bring the wide variety of expertise needed.
- Staged, complementary experiments at increasing precision to address the science

- Bring all necessary resources from other HEP and SC areas,including Supercomputing, Theory, Detector R&D, QIS, AI/ML
- Form mutually beneficial partnerships with NSF, NASA & International

HEP works proactively in partnership with labs & university community to carry out our program.

HEP Strength → Structured Science Collaborations

Science Collaboration Model

- **Support scientists as part of structured science collaborations that brings together all expertise needed**

- **Scientists participate in all phases & activities, leading to the best possible results from state-of-the art projects.**

- **Scientists are intimately involved and have roles & responsibilities in project design & fabrication (hardware, software), commissioning, experimental operations, science planning & data analysis**

- **Students & postdocs are trained by participation in all phases to gain experience and expertise; opportunities to work at a lab or experiment site**

DESI Collaboration meeting, Dec.2025
Credit: KPNO/NOIRLab/NSF/AURA/P. Marenfeld

→Priority for Research support is for efforts directly in line with HEP science goals, roles and responsibilities on our experiment, and is reflected in peer reviews.
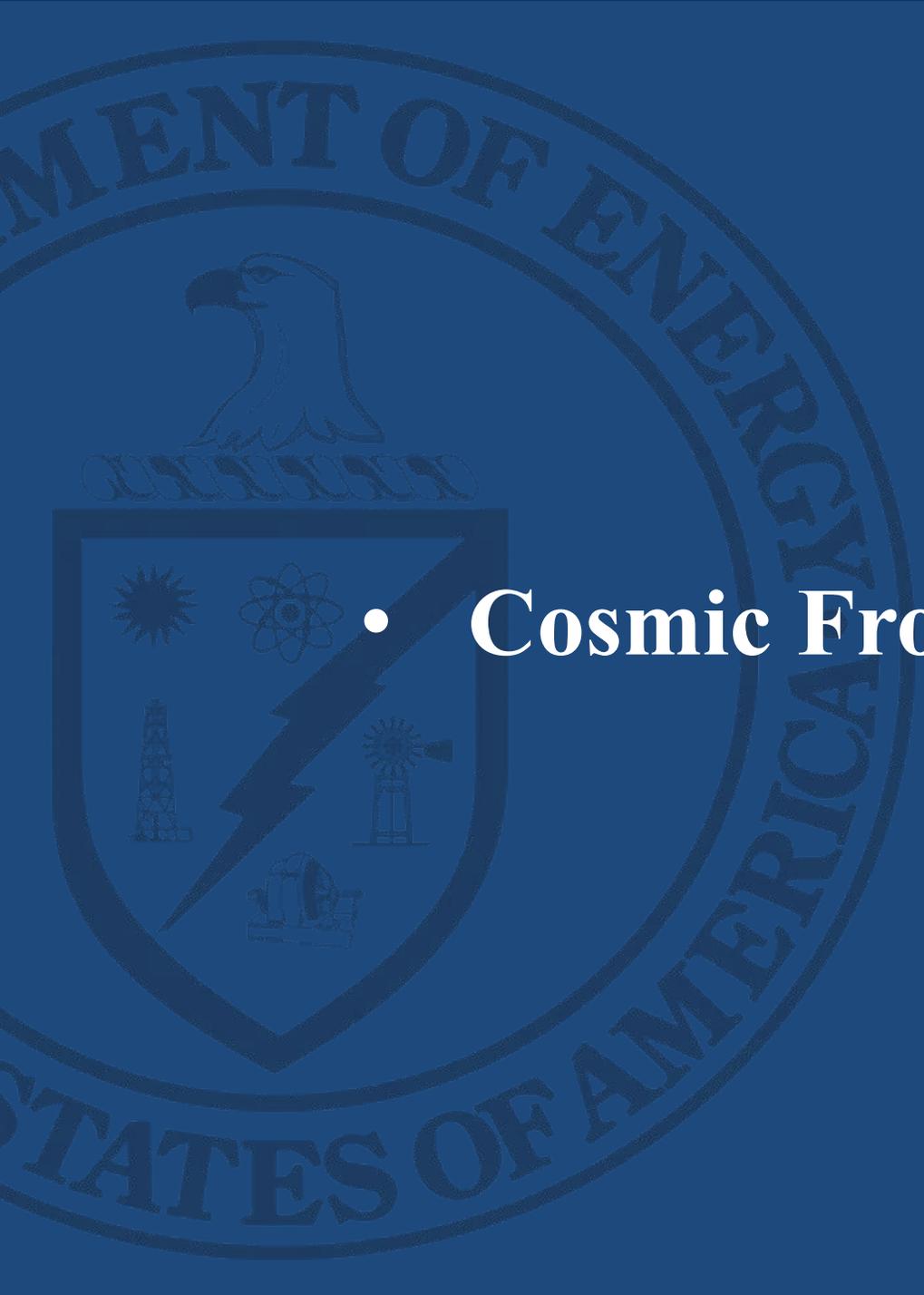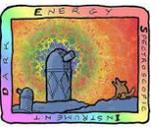
Cosmic Frontier - Cosmology Experiments

-- Imaging and Spectroscopic surveys to determine the nature of Dark Energy + pathfinder to the Dark Ages

2000　　　2005　　　2010　　　2015　　　2020　　　2025　　　2030　　　2035

Credit: NSF-DOE Vera C. Rubin Observatory

Sloan Digital Sky Survey 1, 2

Credit: FNAL
Visual Media Services

DECam/Dark Energy Survey on NSF's Mayall telescope

Imaging observatories

LSST Camera on the NSF-DOE Vera C. Rubin Observatory (First Look June 2025)

Spectroscopic observatories
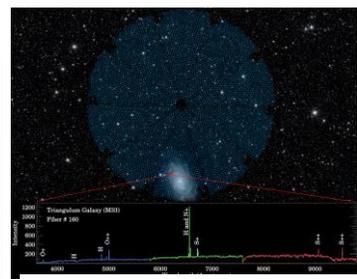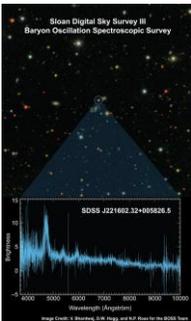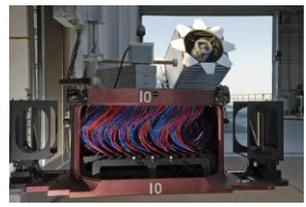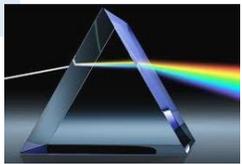
Spectrograph, BOSS, extBOSS on SDSS

Credit: DESI collaboration

Dark Energy Spectroscopic Survey (DESI) through 2028

Community is proposing DESI-II (R&D $ in FY25)

Dark Ages (radio)

LuSEE-Night → to the moon; launch early 2027

Dark Energy Survey (DES)

DOE/NSF partnership: *25 institutions in 7 countries; > 400 scientists, > 438 publications >100 PhD's.*
- Fermilab led fabrication of 570Mpix DECam; NSF led telescope upgrades, data management
- Both agencies supported operations on NSF's Blanco telescope at CTIO in Chile
- 6-year imaging survey of 5100 sq-deg completed Jan. 2019
- FNAL is storing & publicly serving the cosmology data.
- Final cosmology analyses are in progress; talks at the 2026 AAS in Phoenix and see Webinar Jan. 22 at 10:30am CT at https://www.darkenergysurvey.org/des-y6-3x2pt-results-webinar-january-22-2026/

Dark Energy Camera (DECam) on the Blanco

Recent results from supernovae & Baryon Acoustic Oscillations (BAO):
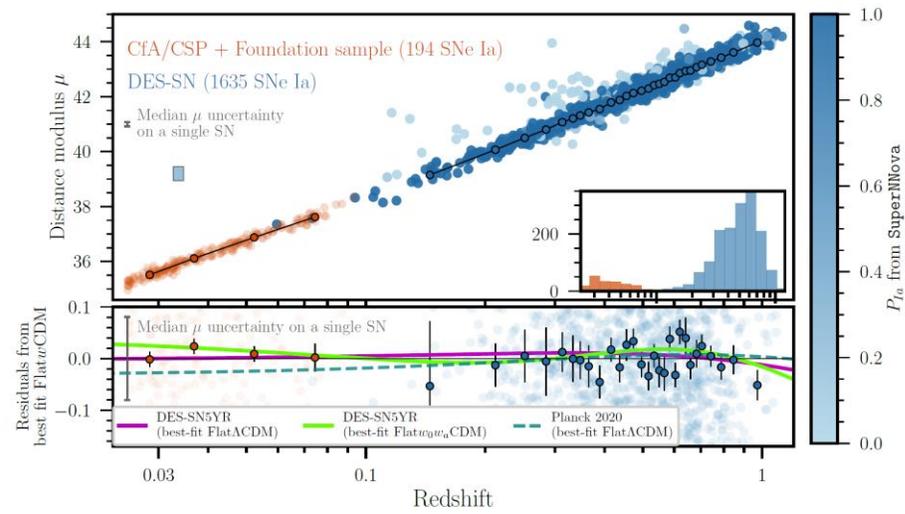
Cosmology results with ~1500 New High-redshift Type Ia Supernovae from full dataset. Results are tightest dark energy constraints from any supernova dataset to date.
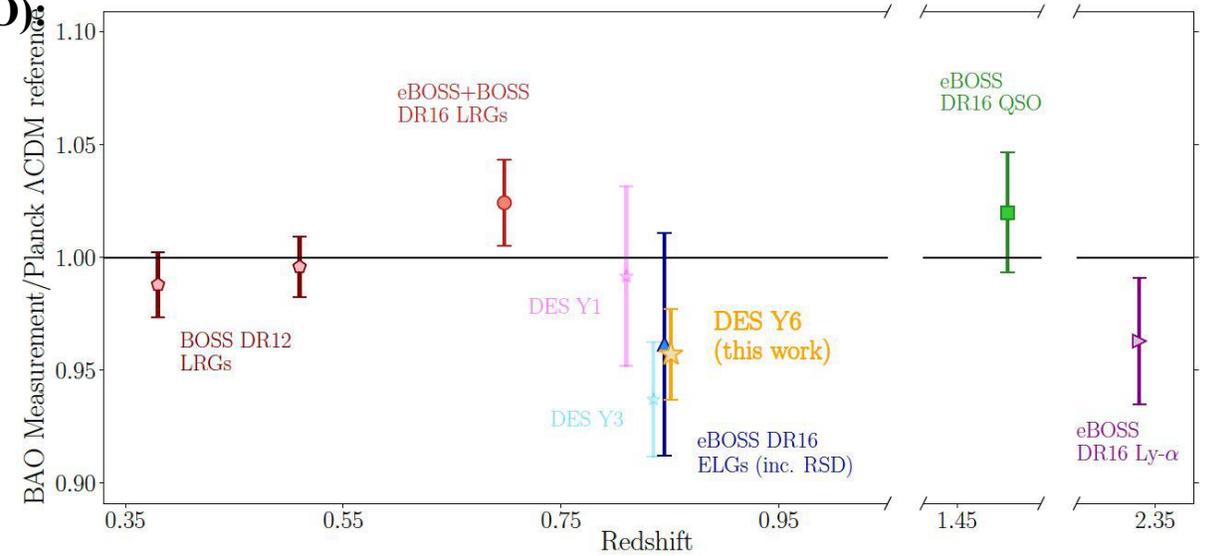
Final BAO results (6 yrs of data) show a 2.1% measurement of the angular BAO Scale. The data show the "Hubble tension" results…difference between Planck (CMB) and dark energy experiments.

DOE's Dark Energy Spectroscopic Instrument (DESI)
→ Stage IV Dark Energy

DESI is led by LBNL: next-generation instrumentation to make big leaps in science measurements and precision.

- Focal plane w/5000 fiber-fed robotic positioners & 10 3-spectral channel (blue, red, near infrared) spectrographs
- DOE "leases" NSF's 4-meter diameter Mayall telescope at Kitt Peak, where DESI is mounted/operated
- Data taking started May 2021 and goes through 2028.
- Collaboration of 800 scientists; about 1/3 are grad students; > 300 publications to date
- Extensive set of published topics: BAO, Neutrino masses, strong lensing…
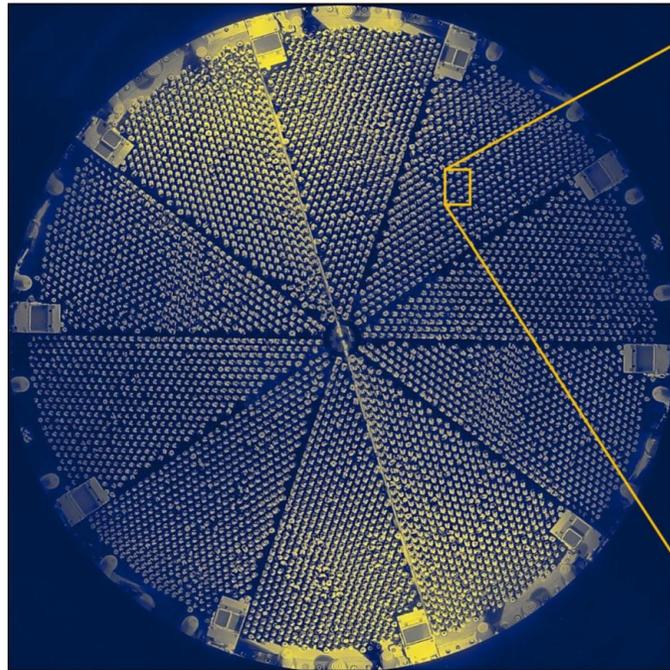
DESI Status, Data

Original 5-year survey (DESI-1)started May 2021 (z < 1.5) → 97% complete dark time; 100% bright time
→ Now extended through 2028 (DESI-1b) to increase original footprint by 20% using new imaging data from Dark Energy Camera Legacy Survey (Data Release 11)

DESI-1 Dark (Nov.2025)
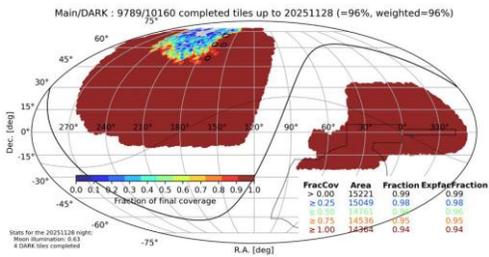
DESI-1 Bright (Nov.2025)

Data → See **https://data.desi.lbl.gov/doc/**
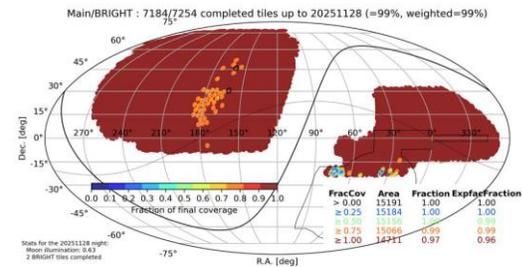
DESI Data Release 1, in March 2025 (Data from May 2021 – June 2022) delivered the largest-ever public catalog of extragalactic redshifts — over 14 million galaxies and quasars — providing a foundational 3D map of the Universe.

DESI DR2 – publicly available derived cosmology data products released Oct. 2025, coinciding with the official publications from DR2

DESI's DR3 – public data release from the original 5-year survey planned late 2026/early 2027
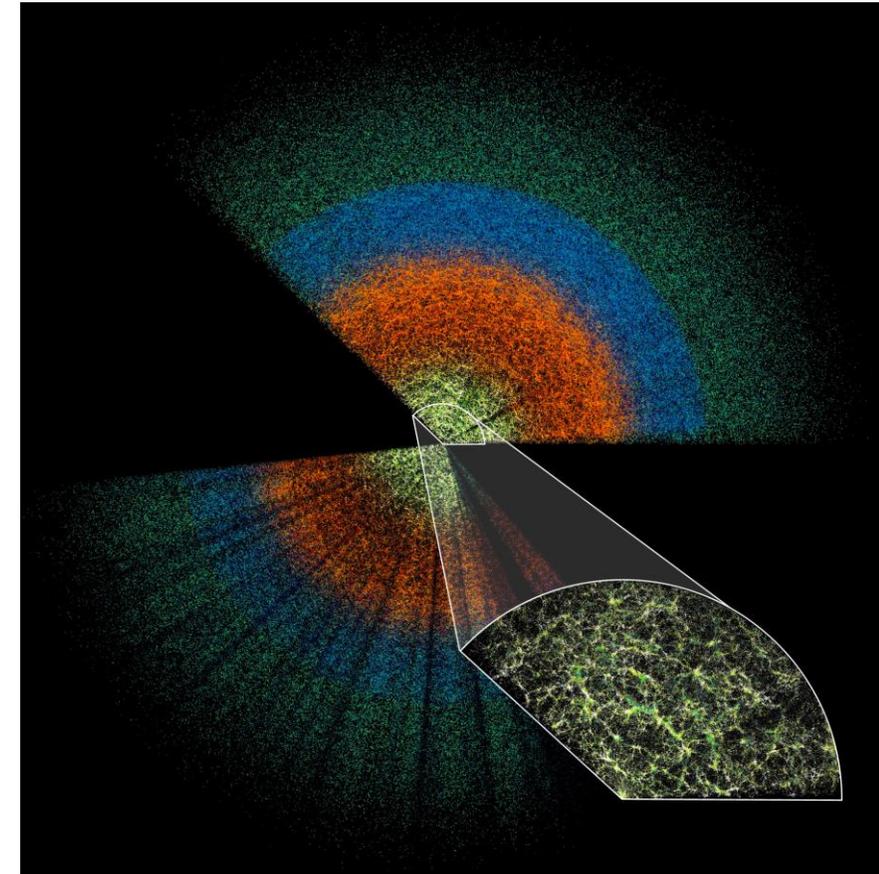
A slice of the Universe mapped by DESI data. The large-scale structure of the Universe is visible in the inset image. Credit: DESI Collaboration/DOE/KPNO/NOIRLab/NSF/AURA/C. Lamman

DESI Results — Hints that Dark Energy May Be Dynamic

Cosmology results from first 3 years of data released at APS on 3/19/25 (==fully blinded analysis==).

- Huge media interest: 1,522 popular articles in 35 languages in first week!

Baryon Acoustic Oscillation (BAO) analysis using a variety of object types from $0.1 < z < 4.2$; record setting BAO precision of 0.3%

→ **Year 3 BAO Key Papers: total 3172 citations (as of 12/10/25)**

o Data consistent with ΛCDM model with cosmological constant

but… **a 3.1σ preference for time-variable dark energy**

o Sum of neutrino masses $\sum m_\nu < 0.064$ eV (ΛCDM) and $\sum m_\nu < 0.16$ eV ($\omega_0\omega_a$)
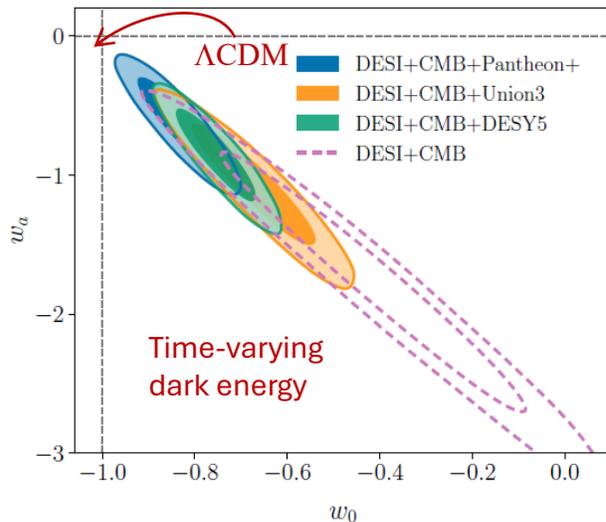
DESI DR2 BAO is the [top HEP citation]
of 2025!
It also was the top HEP 2024 citation.

March 19, 2025

'More Than a Hint' That Dark Energy Isn't What Astronomers Thought
New data further challenge the best scientific theory of the history and the structure of the universe. But a separate recent result reinforces it.

DESI continues to be the world's most competitive instrument for wide-field spectroscopic surveys.

Actual 3D galaxy positions from DESI 3 year data

DESI Awards & Future

- DESI received the AAS 2026 Lancelot M. Berkeley–New York Community Trust Prize
- Daniel Eisenstein **accepted it & gave the prize lecture on behalf of the collaboration at the January 2026 AAS.**

DESI-II (primarily z>2): Collaboration has proposed an upgrade to do ***measurement of dark energy deep in matter-dominated regime;*** ~5000 sq. deg.
- Synergies with other Cosmic Frontier experiments
- Sub-percent precision distance measurements at z>2
- Would extend operations at the Mayall telescope from 2029 to 2035.

Proposed upgrade
- Replacement of the DESI sensors (10 CCDs) in the spectrograph blue channel.
  - New CCD's have sub-electron noise (<0.6e-), improving the sensitivity and allowing higher redshift observations; Working prototypes in hand.
- Imaging surveys for targeting ongoing now: CTIO/DECam, CFHT/Megacam, and others being investigated

DESI and AI/ML - examples

➔ **DESI and other experiments have already made extensive use of AI/ML**

Recent discovery by DESI that Dark Energy is not static but evolves over time

◦ **Use of AI/ML methods to process images and identify features**

◦ Used ML to combine results from multiple experiments and for the first time determine in a model agnostic way, the Dark Energy behavior across the age of the universe (*z*)
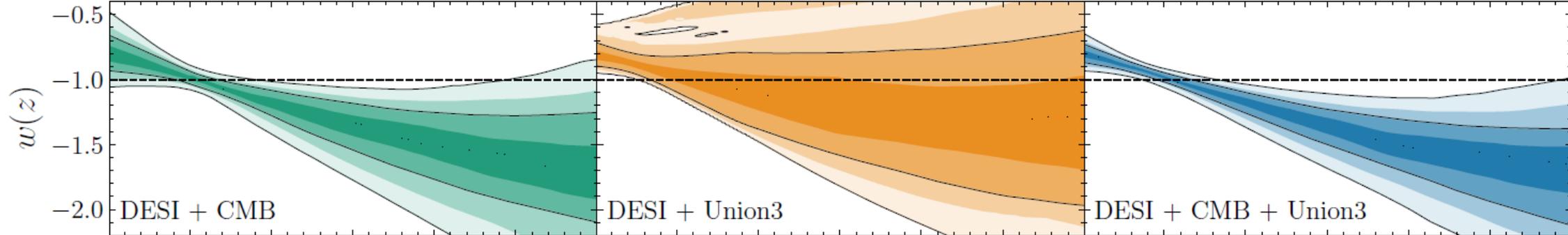
Automated quality assessment using unsupervised machine learning

Efficiently identifies anomalous spectra for expert review

• Applied to DESI DR2's 58 million spectra & flagged 1% of spectra for targeted inspection

➔published in IAU proceedings (August 2025)
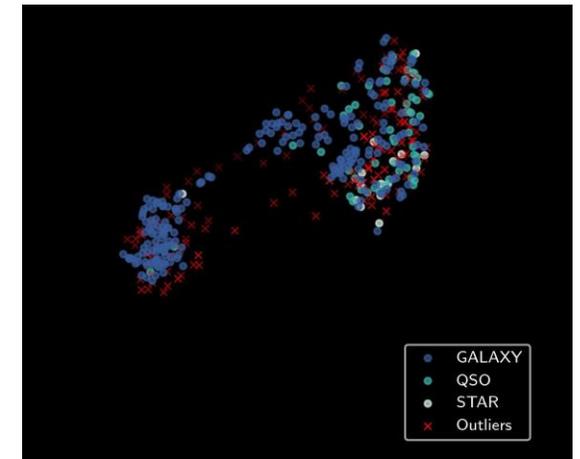
chatDESI Digital Assistant - Web interface for scientists and collaborators to ask technical questions about DESI

NSF/DOE Vera C. Rubin Observatory
w/LSSTCam and Simonyi Survey Telescope

Science: 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
➔ DOE/HEP's primary interest is the Stage IV dark energy

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

Construction/Commissioning responsibilities

NSF (lead) – observatory, telescope, data management, Education/outreach

DOE – LSST Camera fabrication & commissioning

- Both agencies have project management roles and efforts in commissioning, data quality & verification studies.

Operations: DOE & NSF are supporting operations ~ 50/50.
DOE – LSSTCam maintenance/ops, US Data Facility at SLAC, computing, data verification, systems, management roles.

2025 Dr. Vera Rubin quarter
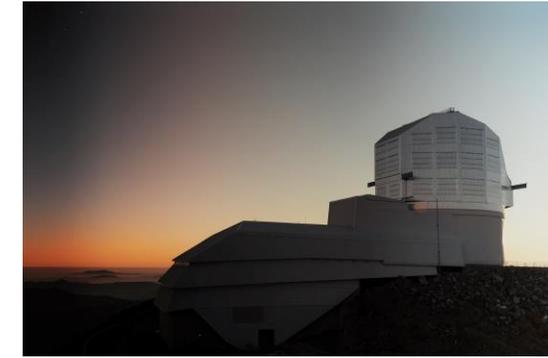
Credit: NSF–DOE Rubin Observatory/NOIRLab/SLAC/AURA/S. Liang

- May 2024: LSST Camera shipped to Chile
- Oct. 2024: First end-to-end observations using Commissioning Camera (ComCam)
- March 2025: LSSTCam installed
- June 2025: **Rubin First Look and Data Preview 1 released;** ComCam data over 7 sq deg in late 2024.
- Oct. 2025: Construction Closeout and Transition to Operations
- Jan. 2026: In Early Optimization Phase
- 2026: **LSST starts**

NSF-DOE Vera C. Rubin Observatory
w/LSSTCam and Simonyi Survey Telescope

Rubin will carry out a 10-year, 800-frame, 6-band, sub-arcsecond resolution cosmic movie known as the Legacy Survey of Space & Time (LSST).

- Fast, deep, wide survey of the southern sky; over the 10 year survey (LSST) will image 20 billion objects, each visited multiple times; sees moving objects – asteroids, variable stars etc.; Full scan of the Southern sky every 3-4 nights

→Will catalog billions of astronomical objects, including galaxies, supernovae, and transient events, revolutionizing time-domain astronomy.

- It will produce an unprecedented volume of high-quality imaging data, enabling groundbreaking studies of dark matter and dark energy through weak lensing and large-scale structure measurements.
- The data will significantly advance our understanding of galactic evolution, the formation of the solar system, and the exploration of the transient and variable universe.
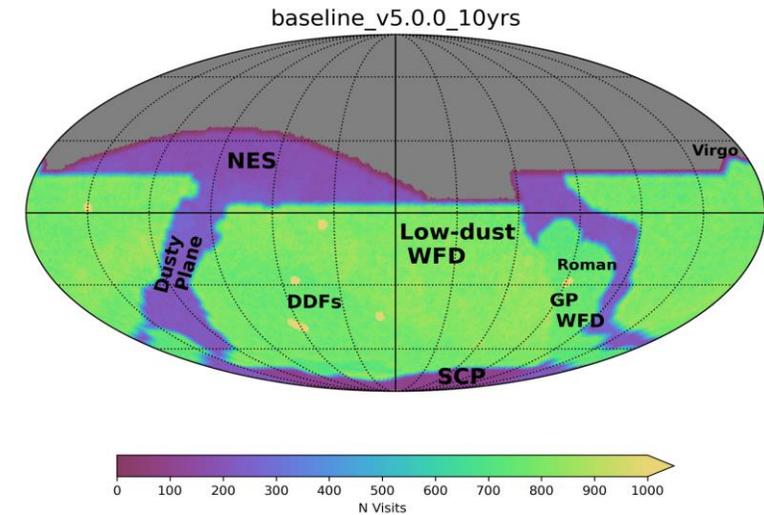
AI/ML efforts with LSST and Rubin
- LSST will provide a rich, huge dataset will support significant scientific studies using AI/ML
- Likely that a significant fraction of science will involve AI/ML
- Rubin Operations is identifying increased efforts to be carried out with AI/ML.

Rubin: Unique, Next Generation Systems ➔ Amazing New Scientific Discoveries

Credit: RubinObs/NOIRLab/SLAC/NSF/DOE/AURA/A. Pizarro D.

Data Management System
20 TB/night transferred to the US Data Facility at SLAC; SLAC carries out data processing for all data & science; Annual catalog, nightly transient alerts
- Major contributions by France, UK

LSST Camera
World's largest wide-field, digital imaging camera with exquisite precision; listed in the Guiness Book of World's Records;
6 filters, near-ultraviolet to near-infrared

Credit: RubinObs/NOIRLab/SLAC/NSF/DOE/AURA/B. Quint

Simonyi Survey Telescope
Wide-field, fast moving & settling with Novel 3-in-2 mirror design
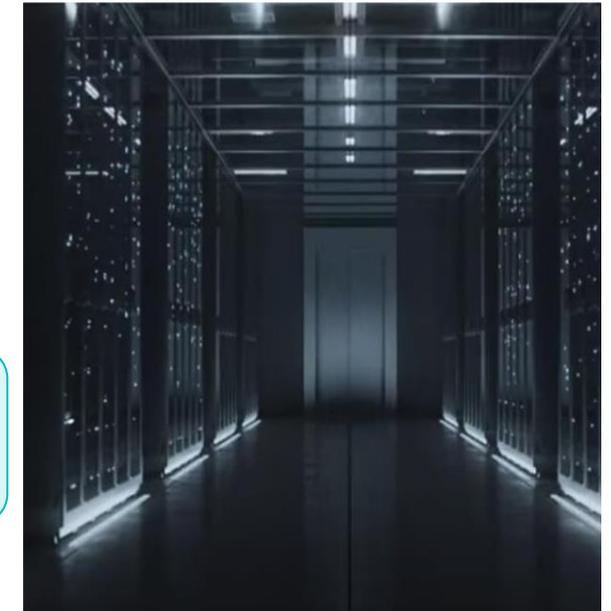
Rubin First Look on June 23, 2025!
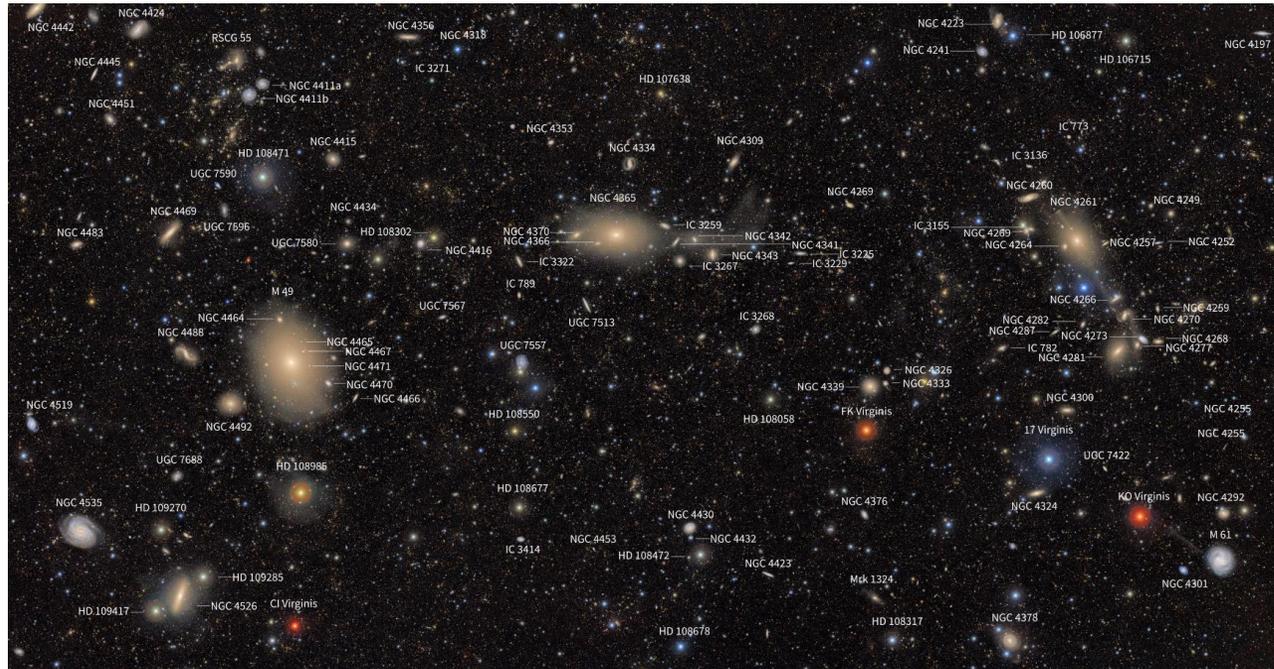
Media event held at National Academies of Sciences →

But was much more

- 200+ people in person at the NAS
- 350+ watch parties
- Several dozen planetarium shows
- live-streamed on 5 YouTube Channels, Vimeo and the DOE X account.

Huge media response – in First 48 hours

- 3,427 total media mentions
- Audience reach: 27.2 Billion (12.8 Billion from "print" media)
- 4K TV mentions, 2.1K Radio mentions
- YouTube: 193K streams of First Look Event
- Rubin Observatory: 941K views
- Social Media: 30K new followers, 2M impressions, 73K engagements
- Added to the Google Discovery Feed!

NSF-DOE Vera C. Rubin Observatory
Construction/Commissioning → Operations

- October 22-24th: Successful review of Construction Completion + Transition to Operations.
- October 25th: Handover of management from the Construction Team to the Operations Team.

Photo Credits:
RubinObs/NOIRLab/SLAC/NSF/DOE/AURA/A. Pizarro D.

Currently in an "Early Optimization" phase to ensure the summit systems consistently deliver the image quality needed. The 10-year LSST is expected to start early in 2026.

DOE/HEP has significant Operations roles and responsibilities across all departments as well as management roles:
- Director's Office – Deputy Marshall and for the LSST (Roodman)
- Summit Operations – Deputy Reil and the LSSTCam Lead Engineer (Lange)
- Data Management- Deputy Alsayyad and US Data Facility Lead (Bolton)

The LSST dataset will be challenging to acquire, process, publish, support, and analyze


- Dataset is too large to distribute: bring users to it
- SLAC also operates the US Data Access Center for large catalog queries, prompt product analysis. Support for up to 10k astronomy and astrophysics users worldwide on the Rubin Science Platform via the cloud.

NSF-DOE Vera C. Rubin Observatory ➔ In the News!

Tony Tyson: Nature's 10 (12/8/25),
"The visionary physicist who gave us a new way to view the cosmos"
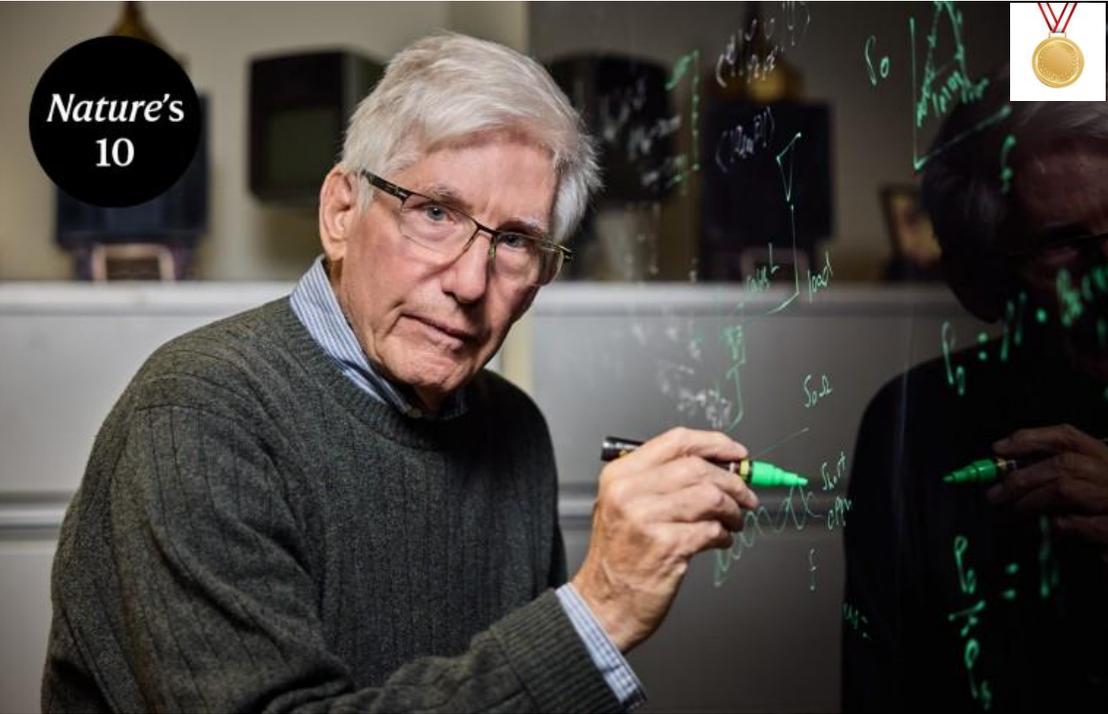
One of Time's Best Inventions of 2025
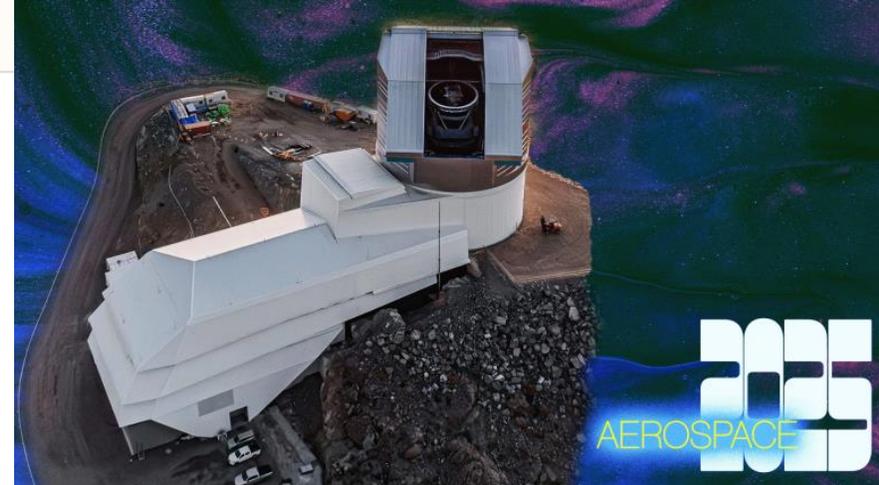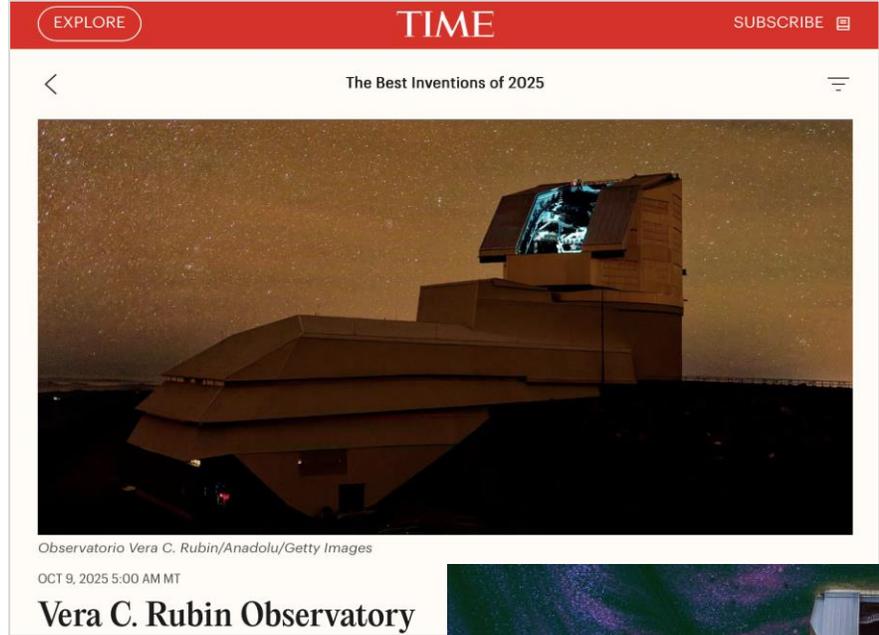
➔ *The excitement continues to build!*

Popular Science Innovation of the Year: World's largest digital camera to conduct 10-year survey of the night sky

Dark Energy Science Collaboration (DESC) Early Rubin Science

U.S. DEPARTMENT of ENERGY | Office of Science

DESC is exercising its pipelines on Data Preview 1 (DP1) and leveraging AI/ML for cosmology to prepare for LSST Observations

Photometric Redshifts for DP1

DESC Photo-z software RAIL applied to the Rubin DP1 Extended Chandra Deep Field South. Eight algorithms, **including 6 ML methods**. Produced training galaxy catalogs, cross-matched with Euclid. (arXiv: 2510.07370)
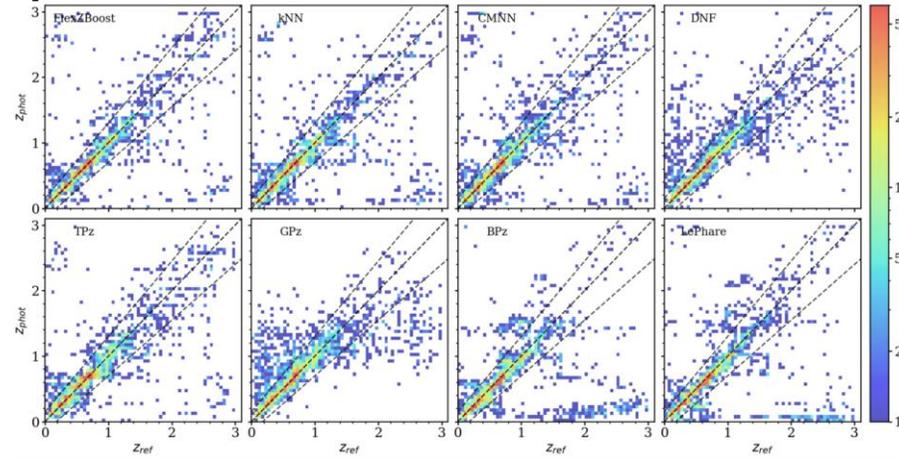
Satellite selection out to 250 kpc for dark matter demonstrated with simulations

Evaluated sensitivity to faint Milky Way satellite galaxies and outer-halo star clusters using simulated resolved stellar populations. With perfect star/galaxy separation, **estimated >50% efficiency.** (Tsiane et al., 2504.16203)
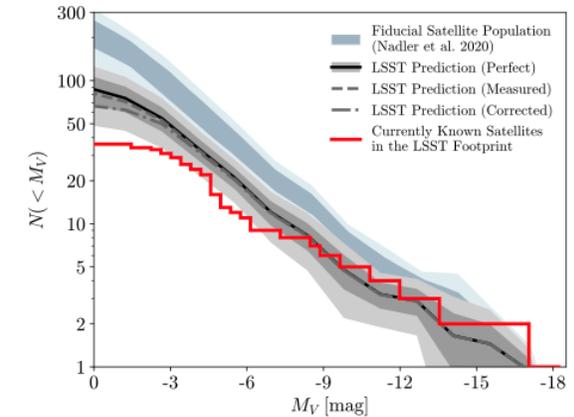
DP1 First weak-lensing measurement

Galaxy cluster Abell 360. DESC members led commissioning work on testing the data quality and **measured the cluster mass with 3 shear algorithms** (in prep).
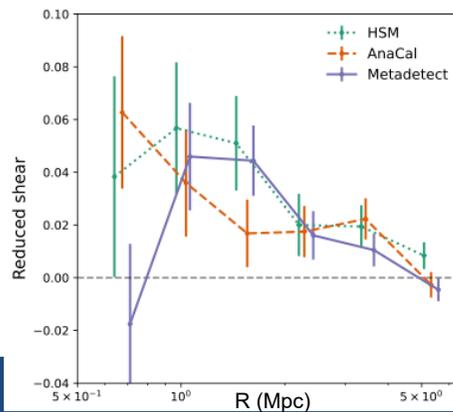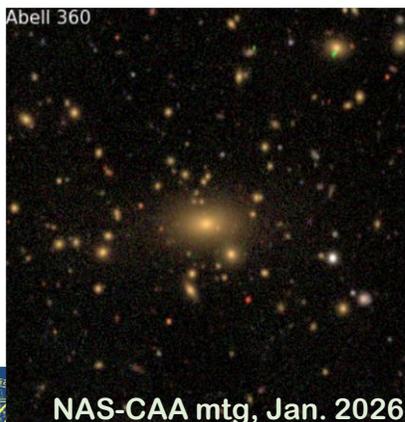
Augmenting samples for redshift calibration

Implemented **machine learning "self-organizing map" technique to augment** samples for photometric redshift calibration yields significant improvements. Tested in CosmoDC2 and OpenUniverse. (Zhang et al., 2508.20903)
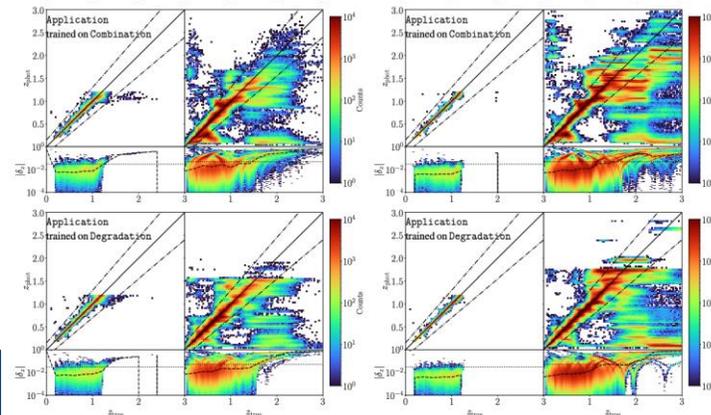
Other AI/ML advances in 2025

- **Hierarchical Inference** for photometric classification of supernovae (Shah+)
- **Cataloging astronomical images** via **Neural Posterior Estimation** (Patel+)
- **Identifying unrecognized blends** with AI/ML (Liang, Adari, von der Linden +)

Dark Ages: LuSEE-Night
- a NASA/DOE Partnership

LuSEE-Night is a radio spectrometer pathfinder that will make the most precise measurements to date of the low-frequency radio sky below 50 MHz; will pave the way toward future discovery of the Dark Ages signal.

Payload on a NASA Commercial Lunar Payload Services (CLPS) mission, to be installed on the far side of the moon

LuSEE-Night Payload

Firefly Aerospace lunar lander
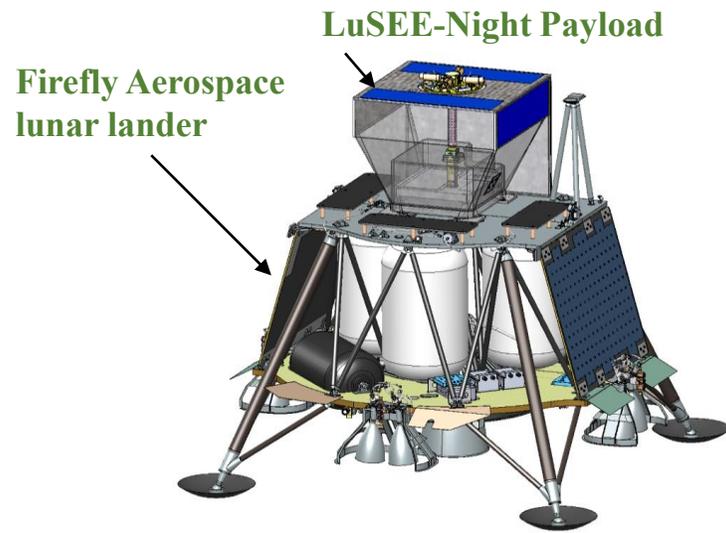
Nov. 2025: Delivery to Firefly

Firefly's Blue Ghost Lander is one of Time Magazine's best inventions of 2025!
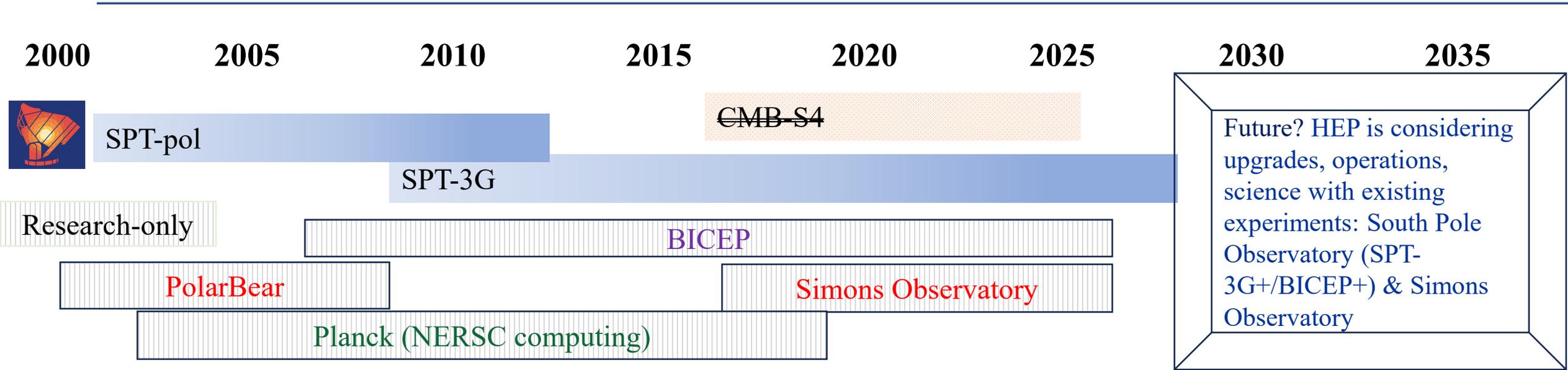https://time.com/collections/best-inventions-2025/7318229/firefly-blue-ghost/

- BNL leads DOE project and operations roles and provides overall Science Collaboration leadership. Space Sciences Lab (SSL) leads the overall LuSEE-Night. BNL delivered all flight hardware to SSL as of Oct. 2024, for payload integration.

Recent news:
- Successful environmental testing at Space Dynamics Lab in Utah (May – Oct. 2025)
- Delivered to Firefly Aerospace on Nov. 12, 2025, to get ready for launch in early 2027

Cosmic Frontier – Cosmic Microwave Background (CMB)

Timeline (2000–2035):

- SPT-pol
- SPT-3G
- Research-only
- PolarBear
- CMB-S4 (~~struck through~~)
- BICEP
- Simons Observatory
- Planck (NERSC computing)

Future? HEP is considering upgrades, operations, science with existing experiments: South Pole Observatory (SPT-3G+/BICEP+) & Simons Observatory

DOE/HEP's CMB research priority for the future - detect gravitational waves from the **Inflation** era to directly confirm or refute the Lambda-CDM model of the universe.

SPT-3G Status

Partnership: DOE-HEP and NSF-OPP, incl. NSF-AST & NSF-PHY
- HEP is supporting ANL, FNAL + other labs, universities.
- HEP supported major upgrade: fabrication of the 16,000-detector focal plane & is providing operations funding.

SPT-3G continues to operate with excellent, high observing efficiency and stable instrument performance

▪ **Survey: Main Survey (1500 sq deg): 6 years complete, Y7 to start in March 2026**
  - Ext-10K survey (10,000 sq deg) complete
  - SPT-3G observations of Euclid Deep Field South Survey (EDF-S) complete
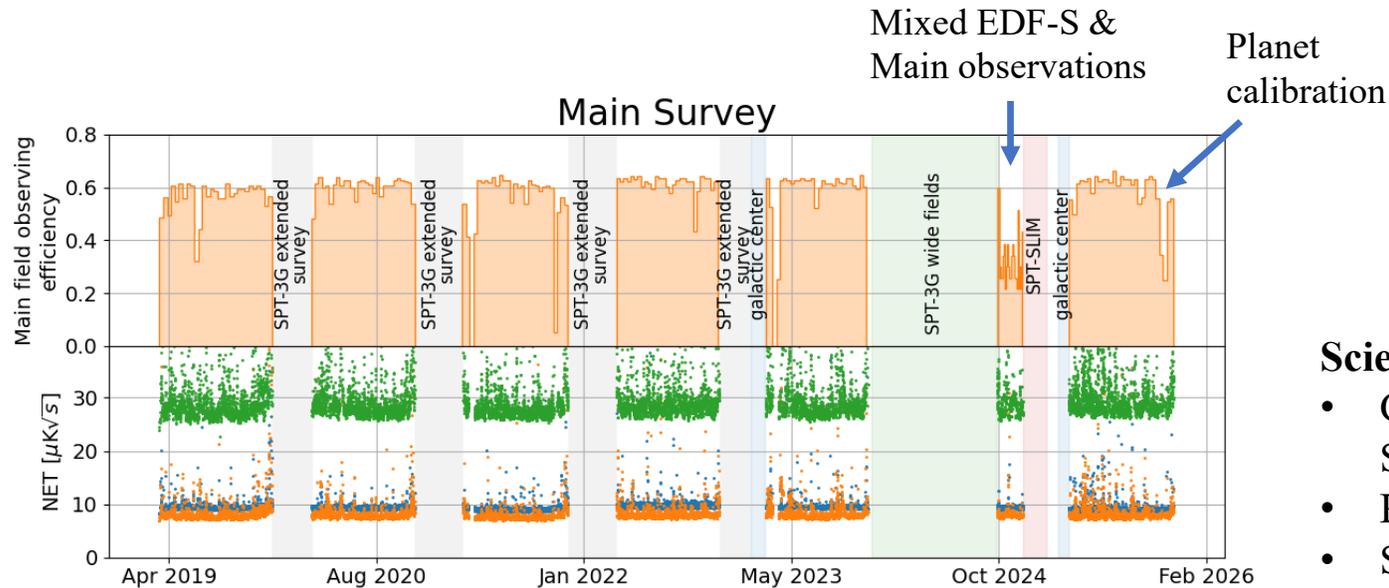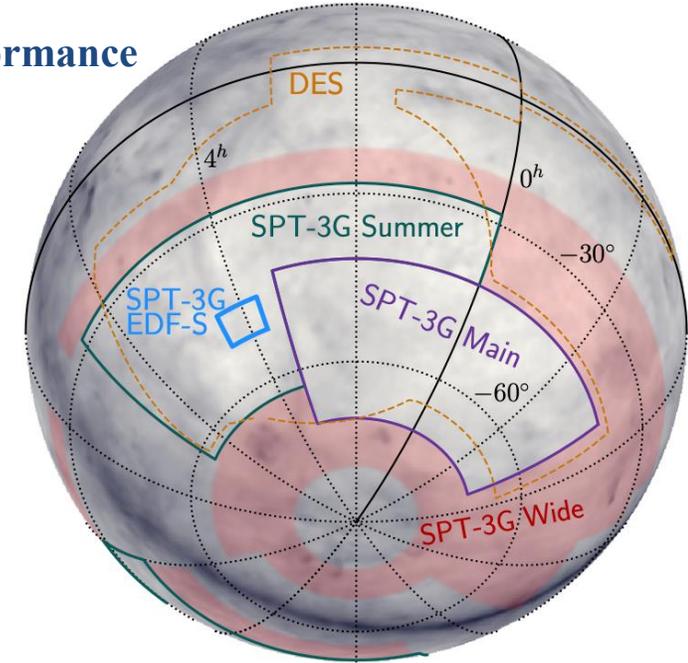

Science & Data Releases:
- Cosmology results using Data set 1 (D1) from 2019/2020 Main Survey released in June 2025 (arXiv: 2506.20707).
- Public release of D1 map products planned for early 2026.
- SPT-3G observations of EDF-S released (arXiv:2506.00298)

SPT-3G Data Set 1 Cosmology Results

- SPT-3G measurements of the EE & TE spectrum are most constraining to date at $\ell=1800-4000$, $\ell=2200-4000$, respectively
- Power spectra are well-fit by ΛCDM model
- $H_0 = 66.66 \pm 0.60$ km s^{-1} Mpc^{-1} from SPT-3G alone (6.2σ away from SH0ES local distance probe)
- Constraining power from ground-based CMB experiments (SPT, ACT) in combination surpass the Planck satellite!
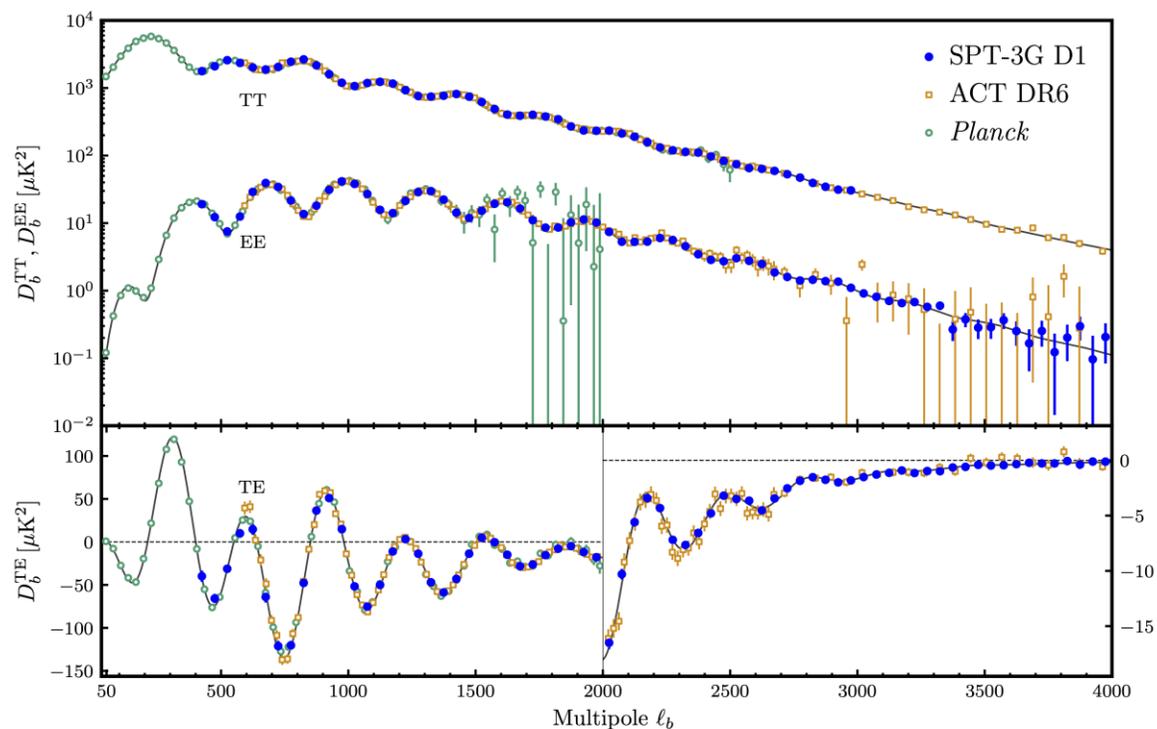
arXiv: 2506.20707
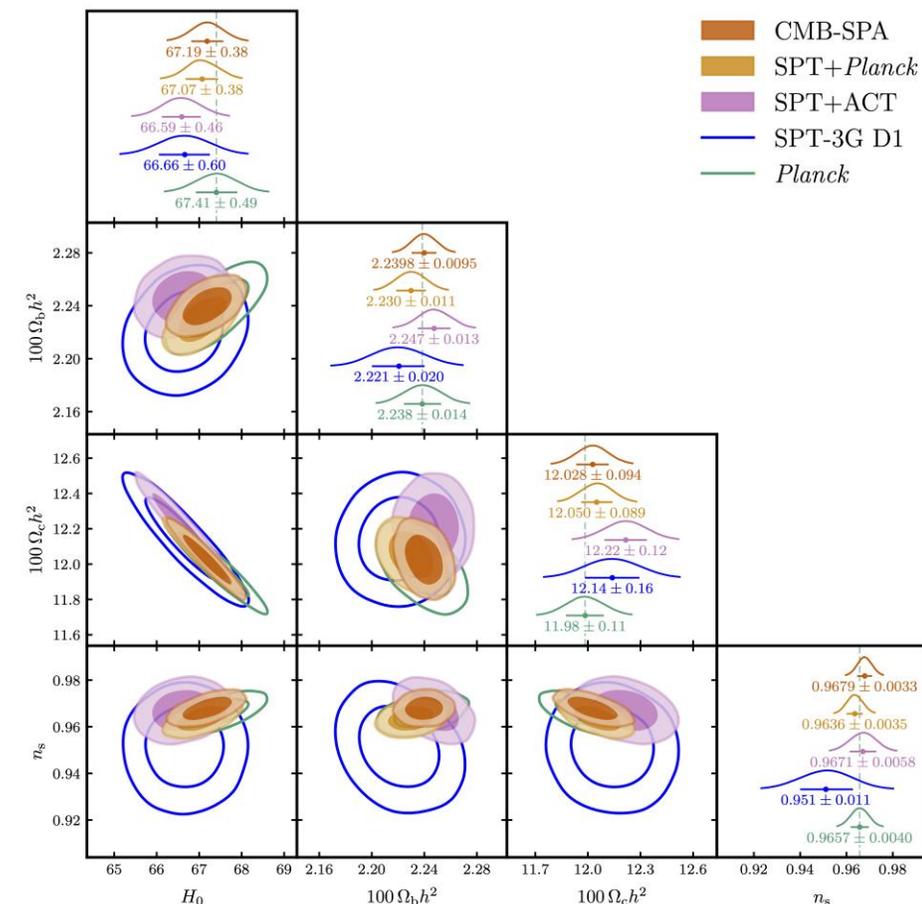
CMB-SPA = SPT, Planck, ACT

CMB Stage 4 – History Part

2014 P5 recommendation: **CMB-S4** as the next step for CMB Research
DOE's priority science goals → Inflation science: gravitational waves from the Inflationary era.

2015-2022: **Original planning** for two-site project – as a DOE/NSF partnership
- 4 major Science Goals best carried out by two-sites, South Pole and Chile, each w/large and small telescopes
- **South Pole site was felt to be critical for Inflation**

South Pole Site (SP is managed by NSF)

2023 P5 recommendation: CMB-S4 w/two sites is top-ranked new project

May 2024, NSF announcement
- No significant new instrumentation or infrastructure at the South Pole for ~ a decade…due to need to prioritize the recapitalization of critical infrastructure
- CMB-S4 was not moved into the MREFC design pool.

Sept 2024: DOE & NSF charged CMB-S4 to develop a **Revised Project** plan w/no significant new effort at the S. Pole

Chile (Atacama) Site

May/June 2025: CMB-S4 reported on a **Revised Project** Plan
- New instrumentation in Chile only: Additional large & small telescopes at the Simons Observatory site
- Assumes current experiments w/upgrades continue at the S. Pole and Chile

CMB-S4 → Now Planning with Current Generation experiments

July 2025 → DOE & NSF jointly decided to not continue to support CMB-S4. HEP is pursuing other options to address the scientific goals.

- **We continue to meet regularly with NSF to discuss opportunities and plans. We will coordinate efforts w/NSF, while considering what's best for our program.**

✓ **DOE is working with the CMB community to further this important US-lead research, aligned with our scientific mission. Our priority is to move forward to make science progress in the near term.** (As always, this depends on funding availability).

Met with South Pole Observatory (coordinated effort of BICEP + SPT) and with Simons Observatory to investigate their status, capabilities, needs, and plans for near-term technology and science progress.

- **Upgrades, continued operations and science analysis can provide significant progress towards Inflation measurements (within factor ~ 3 compared to S4) over the next decade.**

Currently:
- Supporting scientists on both SPO and SO
- Considering upgrade contributions to SPO (provided FY25 R&D $) – primarily detectors, electronics
  - Continues our history of SPT contributions; BICEP upgrades are also needed for Inflation science
  - In partnership with NSF
- Considering contributions to SO in data/computing in support of operations to enable continued science progress. (provided FY25 Ops $)
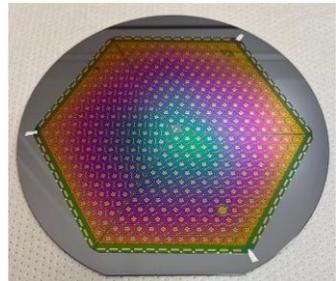
Cosmic Frontier - Dark Matter (Direct-Detection) through 2035
➔ Variety of technologies, masses and particle types

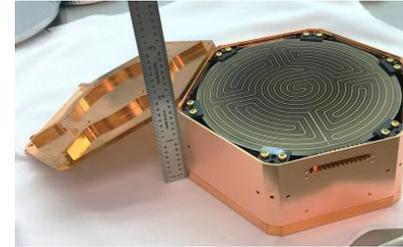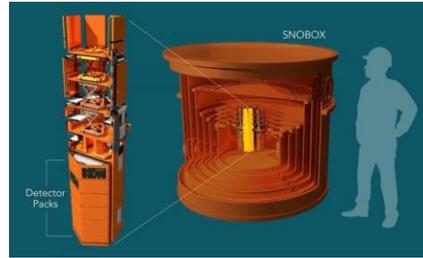**2000**   **2005**   **2010**   **2015**   **2020**   **2025**   **2030**   **2035**

SuperCDMS-Soudan (Minnesota)

SuperCDMS-SNOLAB (Canada) – starts late FY26

➔Also accelerator - based and astrophysical survey based dark matter searches.

Large Underground Xenon (LUX) – S. Dakota

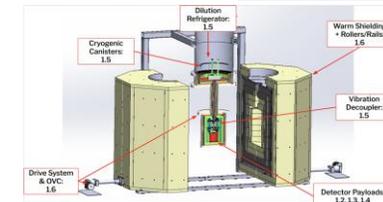LUX-ZEPLIN (LZ)   Operating in S. Dakota

Community is investigating future upgrades & experiments.

ADMX-II
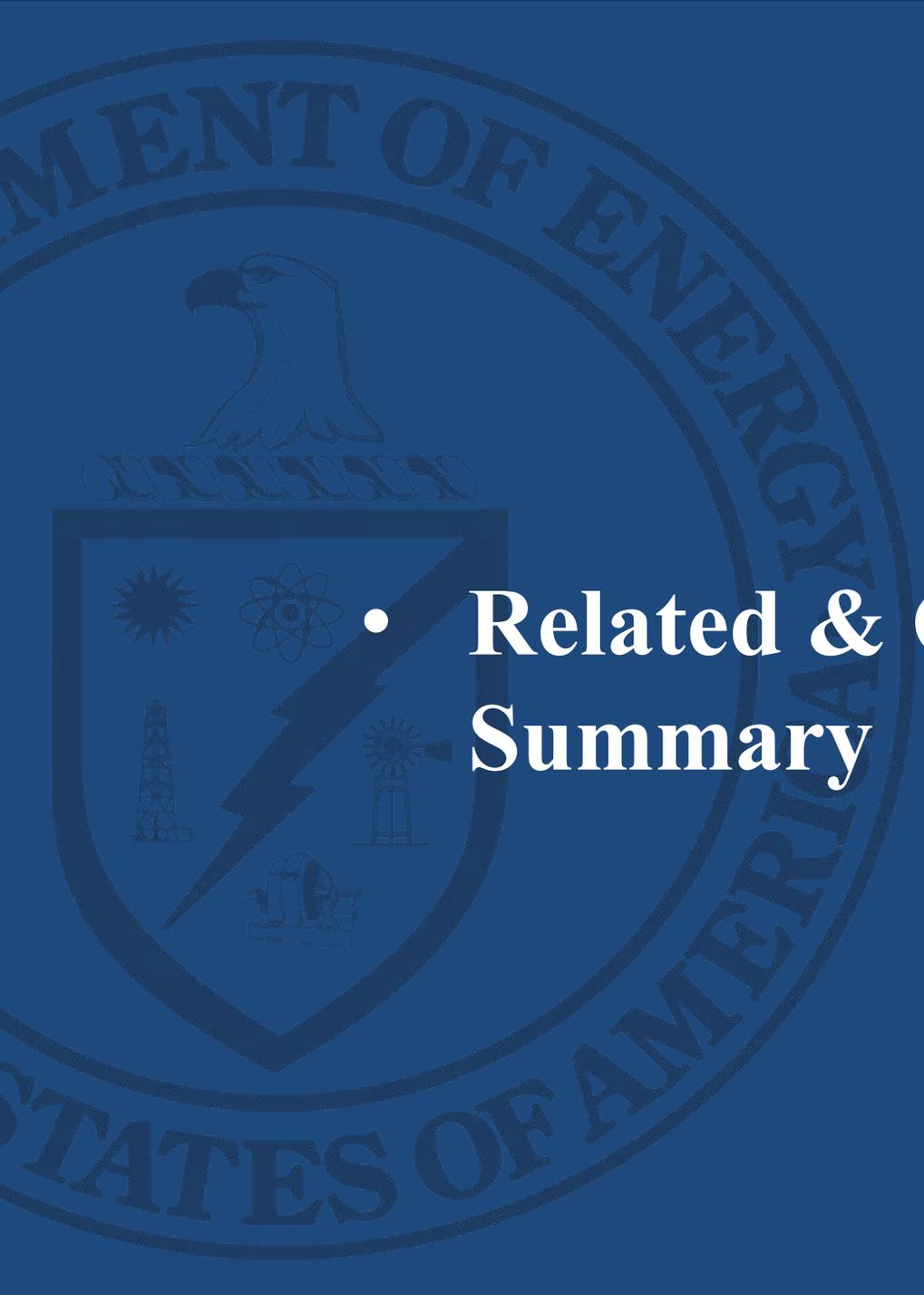
ADMX-G2   Operating at U. Washington


Credit: Lamestlamer

Dec.2025: LZ – new World-leading Results
- Largest DM data set (417 live days), March '23 - April '25
- <u>World-leading limits</u>: No sign of WIMPs 3 GeV/c^2 to 9 GeV/c^2
- <u>Strongest evidence</u> yet of boron-8 solar neutrinos interacting with Xe atoms through a rare process called "CEvNS", building on hints from other experiments.

TESSERACT in France – In Fabrication

HEP Detector R&D Program
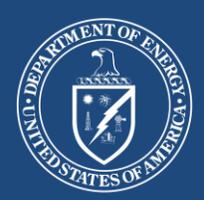
✓ **Support research leading to fundamental advances in the science of particle detection and develop the next generation of instrumentation for HEP**

✓ **Provide (under-)graduate and post-doctoral research training in instrumentation**

✓ **Support 'infrastructure' (technical personnel, equipment, 'facilities', and test beams) required for experimental detector R&D and fabrication**
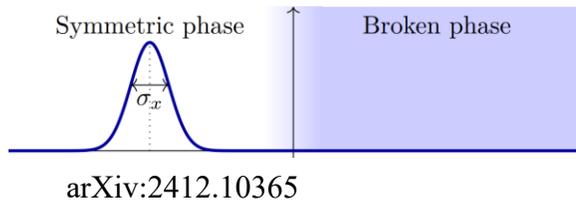
Cosmic Frontier related R&D includes:

- Advanced Sensors: TES, MKIDs, SNSPDs, qubits, CCDs,…

- Electronics: SQUIDS, LC elements, multiplexing,…

- Low-threshold LAr/LXe TPCs

- Ultra-low background assaying techniques and materials

QIS at the Cosmic Frontier

Quantum Information Science at DOE HEP

QIS theory for foundational physics

Quantum computing and simulation

Quantum sensing for new signals

Theoretical approaches to gravitation, black holes, and QFT in dynamic spacetime

Simulations of early universe, e.g., asymmetry generation

HEP-QIS research is pursuing tech for axion dark matter searches from 10^{-12} eV – 1 eV

arXiv:2412.10365

Photon/phonon detection with qubits

Beyond-SQL quantum amplifiers
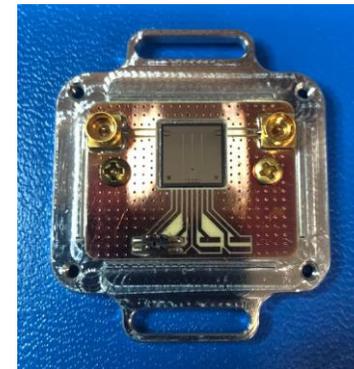
Irwin Group, SLAC

arXiv2102.02619
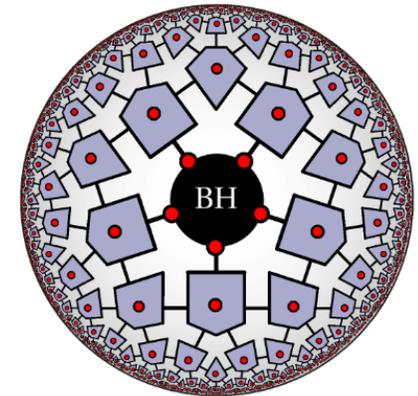
Kurinsky Group, SLAC

Precision magnetometry using entangled spins and cold atoms
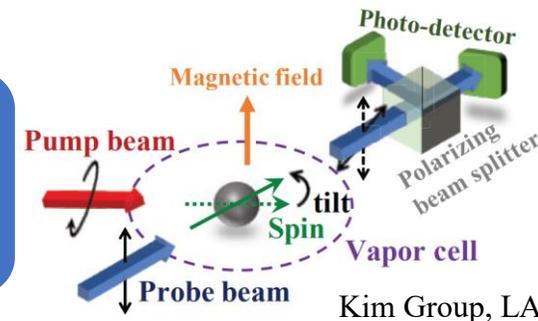
Kim Group, LANL
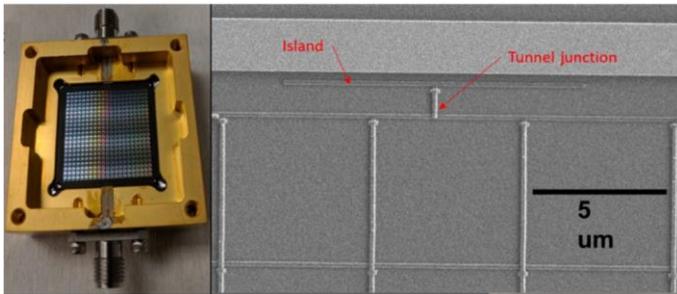
Data Management

Collaboration	Data Rate	Stored Data	Compute Facility
AMS-02	10 MB/sec 40 TB/year RAW	253,465,130,175+ events 22.6 PB of data at CERN	Payload Operations Control Center at CERN
Dark Energy Survey (DES)	Data taking completed in 2019.	120 TB RAW 1.5 PB Higher-Order products	NCSA, UIUC Campus Cluster, Fermilab, NERSC
Dark Energy Spectroscopic Instrument (DESI)	100 GB/night RAW 1 PB/year total	EDR is 80 TB (1.8M objs) DR1 is 1.2 TB (18M objs) DR2 is 10 TB (40M objs)	NERSC
South Pole Telescope (SPT-3G)	Several TB/day RAW	Several PB RAW and processed https://lambda.gsfc.nasa.gov/product/spt/	ANL, U Chicago, NERSC (BICEP/KECK and SO as well)
NSF-DOE Vera C. Rubin Observatory	20 TB/night 30 PB/year RAW	Rubin Science Platform https://data.lsst.cloud/	US Data Facility at SLAC, UK Data Facility, France Data Facility
LSST DESC	Processed data from Rubin	Expected 15 PB	NERSC, IN2P3, SLAC

DOE projects have successfully created, analyzed, archived, and served some of the largest scientific datasets ever created and operates several of the world's leading supercomputers such as Frontier (ORNL), Aurora (ANL), and NERSC.

SUMMARY

Great science is happening in the Cosmic Frontier and in the Office of High Energy Physics.

→ Looking forward to more exciting data and results to come!