HEP to DPF

High Energy Physics
May 21, 2026

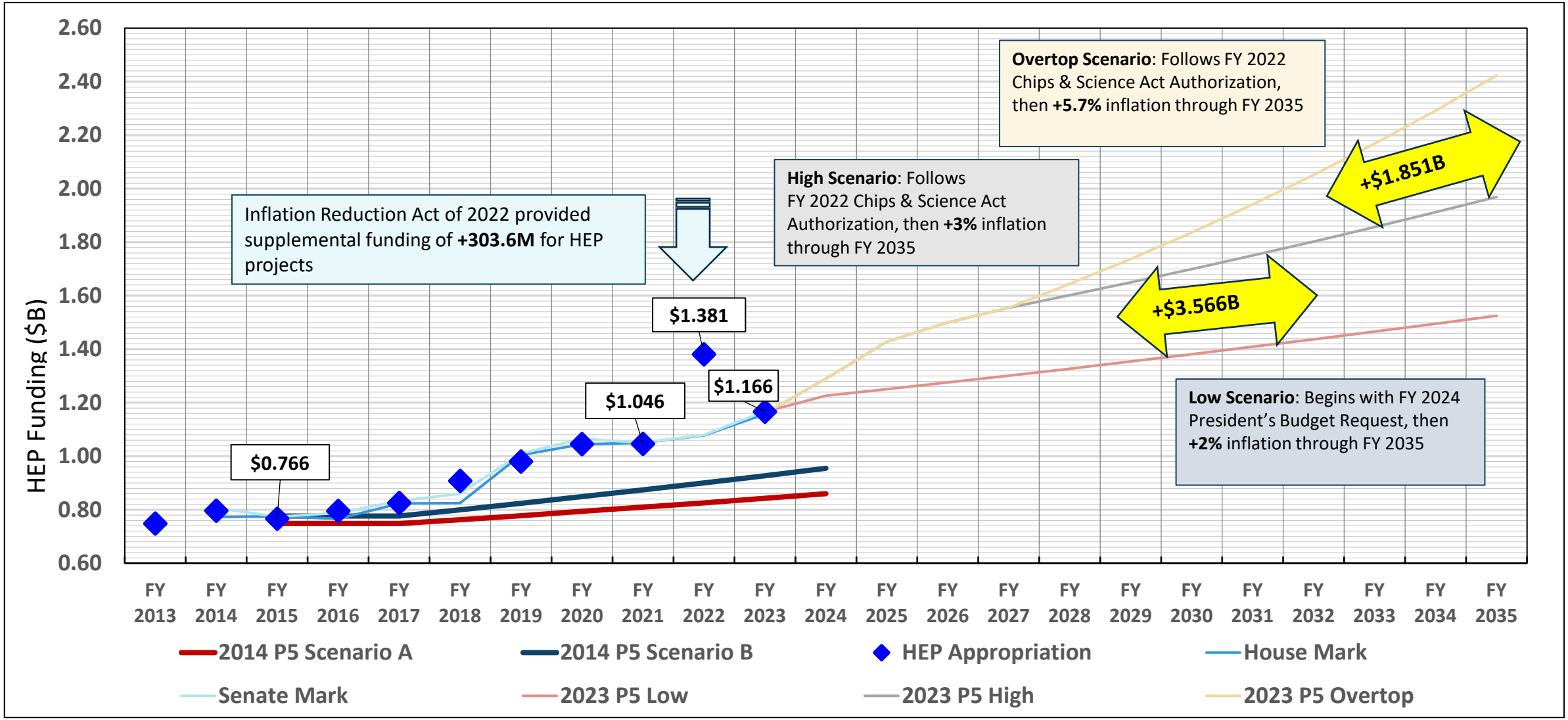
Regina Rameika

U.S. DEPARTMENT of ENERGY | Office of Science

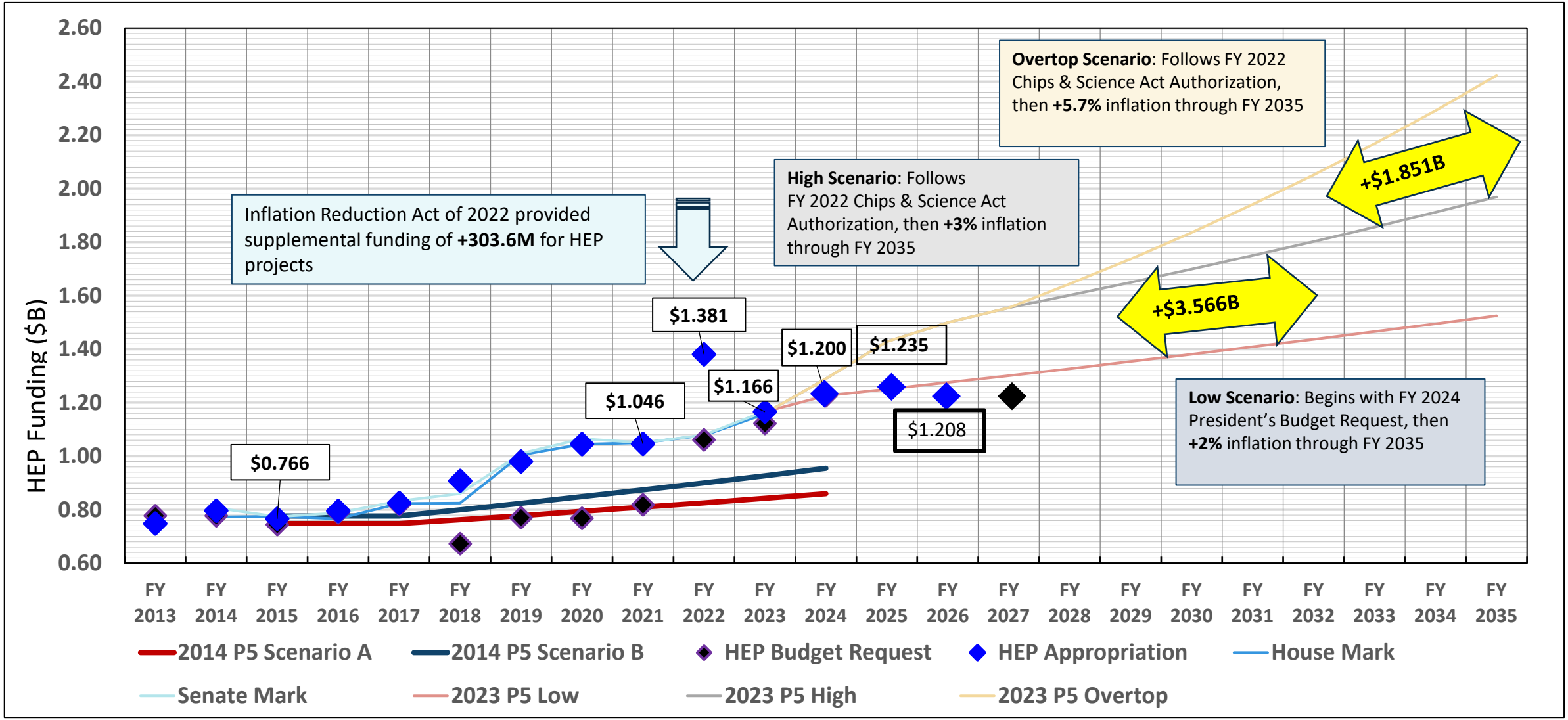
Topics for today

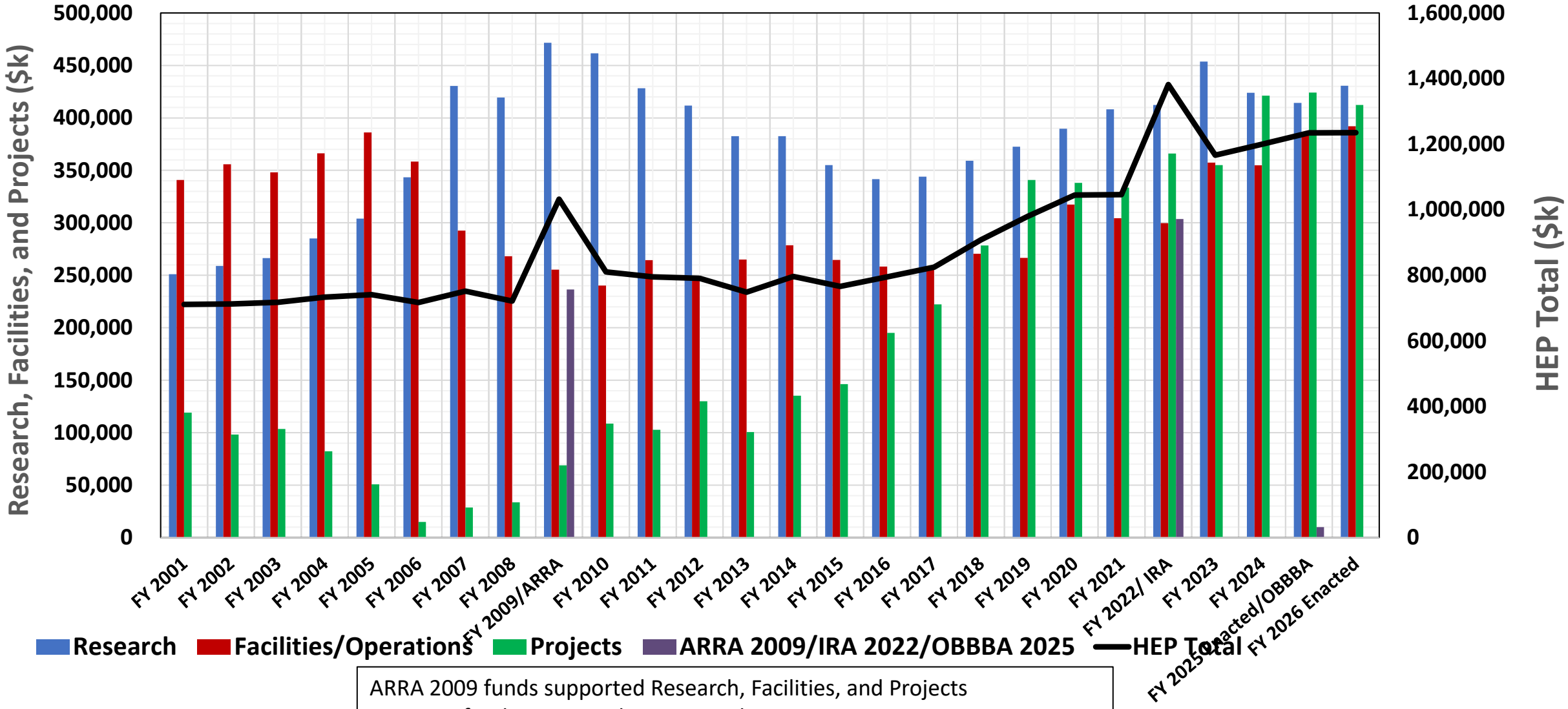
- 2023 P5 Budget Planning Assumptions
- Actual HEP budget 2023 – 2026 + FY27 PBR
- Status of implementing P5 recommendations
- HEP Project Portfolio
- FY25 to FY26 budget comparison
- The next 5 years
- Outlook for new projects
- P5 Recommendation #6

2023 P5 Budget Scenarios



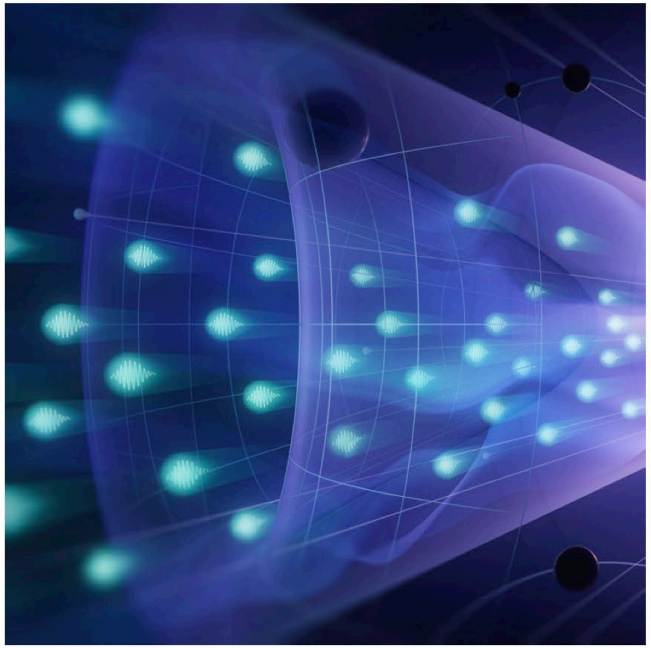
2023 P5 Budget Scenarios





ARRA 2009 funds supported Research, Facilities, and Projects
IRA 2022 funds supported Projects only
One Big Beautiful Bill (OBBA) of FY 2025 funds Research only
FY 2026: formerly ARDAP program funds are merged into the HEP Budget

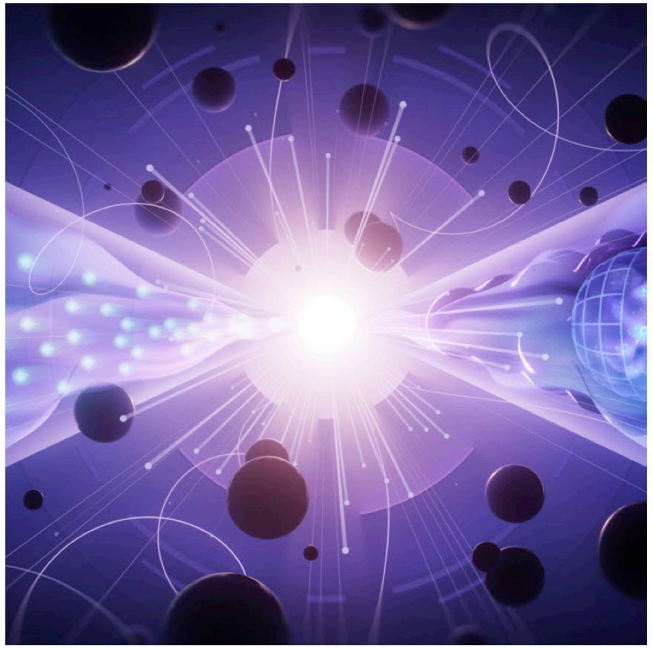
P5 2023 Science Drivers



Decipher the Quantum Realm

Elucidate the Mysteries of Neutrinos

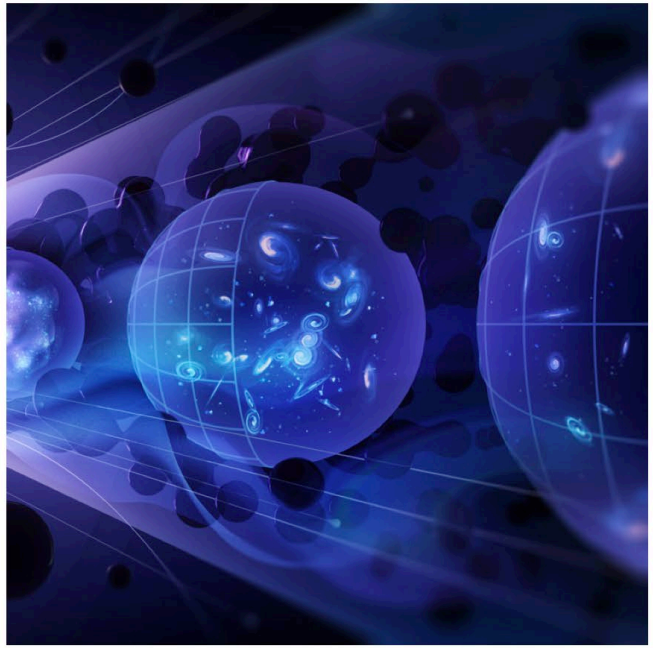
Reveal the Secrets of the Higgs Boson



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

Exploring the Quantum Universe

Recommendation 1

Not Rank-Ordered

As the highest priority independent of the budget scenarios, complete construction projects and support operations of ongoing experiments and research to enable maximum science. We reaffirm the previous P5 recommendations on major initiatives:

a. **HL-LHC** (including ATLAS and CMS detectors, as well as Accelerator Upgrade Project) to start addressing why the Higgs boson condensed in the universe to search for direct evidence for new particles to pursue quantum imprints of new phenomena and to determine the nature of dark matter.
b. **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.
c. **The Vera C. Rubin Observatory** to carry out the LSST, and the LSST Dark Energy Science Collaboration, to understand what drives cosmic evolution.

DOE HEP is in complete agreement with this recommendation for a, b and c; However :

Final funding for HL-LHC in FY27 completes the baseline funding level of $200M for each detector. However, significant activities, including some deliverables and I&I are going to have to be funded from the operations budget.

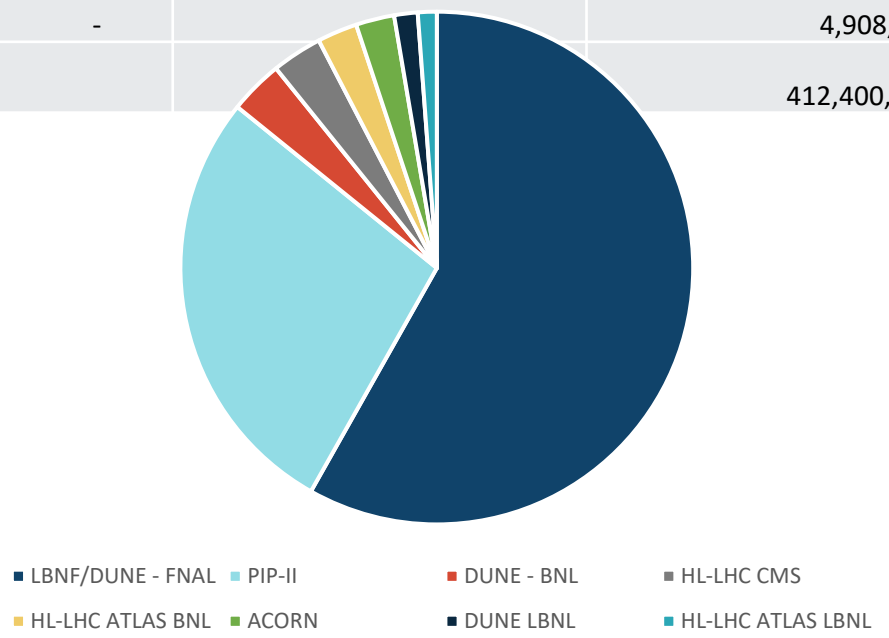
The estimate at this time is a need for an additional $25M per detector, over the years FY27 –FY30, above the annual operations budgets of $25-27M per detector.

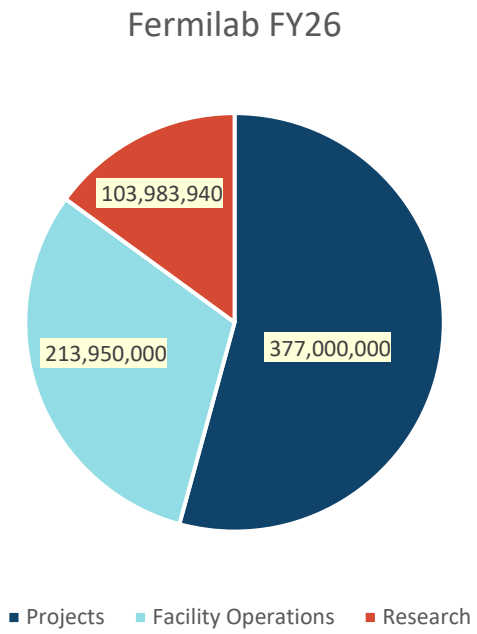
There are many issues with DUNE, including the current Total Project Cost, which needs to increase to accommodate the cost of the near site conventional facilities which came in a factor of 2 higher than planned at CD-1RR

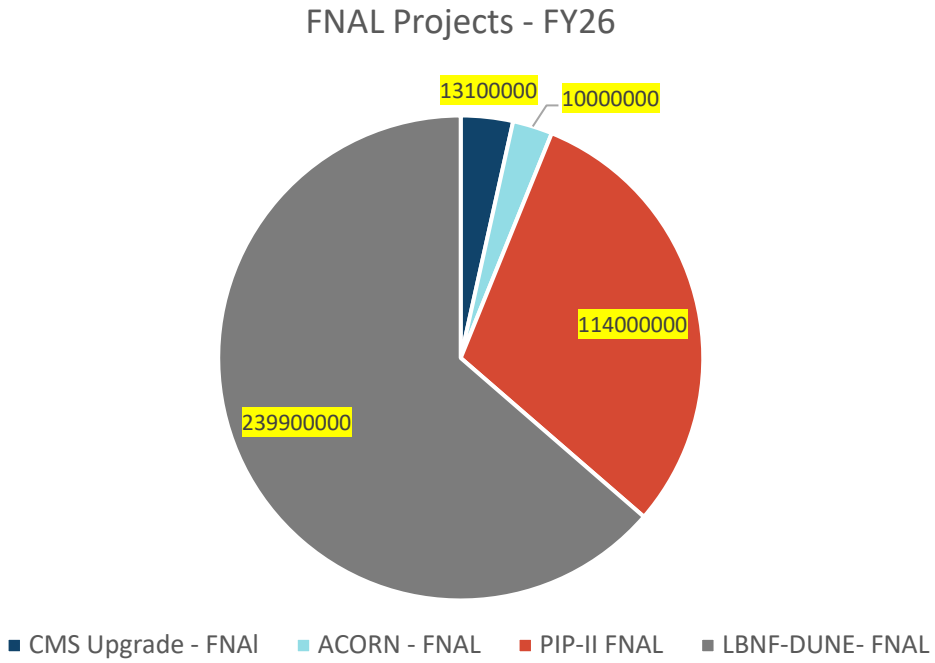
The Rubin Observatory is now in operations, with an annual operations need of $35M

HEP Projects

	FY 2023 Annual Plan	FY 2024 Annual Plan	FY 2025 Annual Plan	FY 2026 Budget Plan
LBNF/DUNE - FNAL	172,600,000	238,000,000	236,700,000	239,900,000
PIP-II	120,000,000	125,000,000	125,000,000	114,000,000
DUNE - BNL	7,400,000	13,000,000	14,300,000	14,000,000
HL-LHC CMS	10,000,000	19,500,000	17,500,000	13,100,000
HL-LHC ATLAS BNL	3,389,000	12,096,000	13,450,000	10,392,000
ACORN	2,000,000	5,000,000	10,000,000	10,000,000
DUNE LBNL	-	-		6,100,000
HL-LHC ATLAS LBNL	-	-		4,908,000
Total Projects				412,400,000







	LBNF/DUNE Funding Profile									
	Thru FY23	**FY24**	**FY25**	**FY26**	**FY27**	**FY28**	**FY29**	**FY30**	**FY31**	**Total**
CD-1RR	1261	255	305	305	305	305	290	251	-	3,277
Current	1261	251	251	260	305	305	305	305	43	3,277

> $100M behind the CD-1RR plan

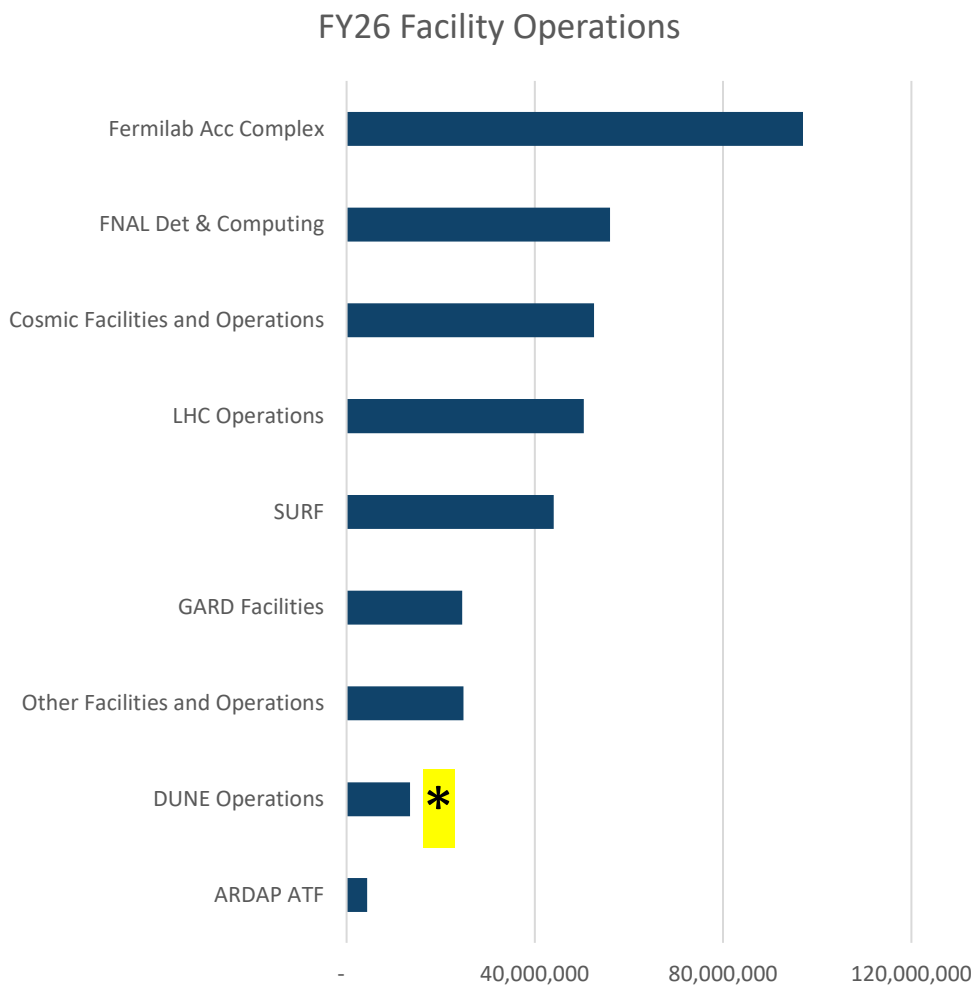
Project can not meet scope with this TPC

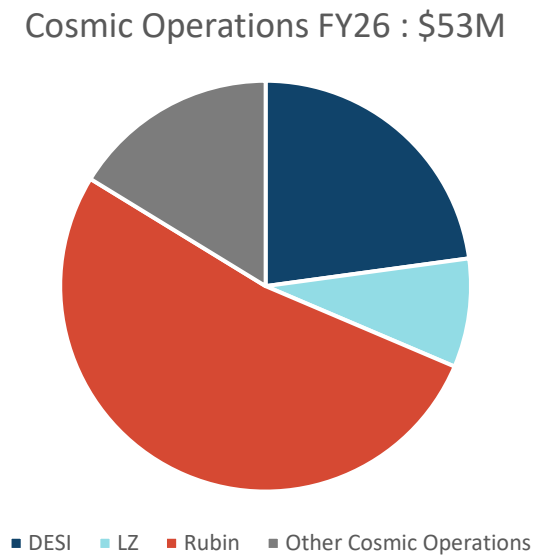
FY 2026 to FY 2031: HL-LHC Project I&I Profiles

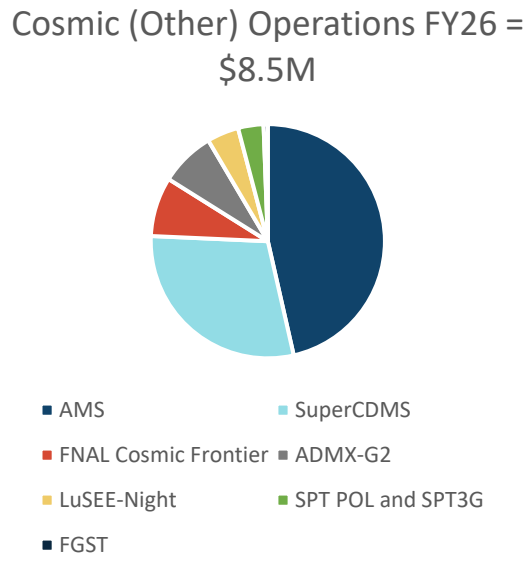
[in $k; Preliminary Data from U.S. HL-LHC Projects and LHC Operations]	FY 2026	FY 2027	FY 2028	FY 2029	FY 2030	FY 2031	TOTAL
ATLAS Installation & Integration (*ver.* Oct 2025)	-	-	2,580	3,649	4,066	1,583	**11,878**
ATLAS Technical Deliverables - Objective KPP Scope (*ver.* Oct 2025)	-	4,267	5,900	2,982	-	-	**13,149**
CMS Installation & Integration (*ver. Mar* 2026)	-	3,360	5,766	5,159	4,712	1,000	**19,997**
CMS - DOE-NP ETL (*ver. Mar* 2026; Amounts include $1.2M contingency)	132	1,172	1,586	1,859	1,198	-	**5,947**
TOTAL	**132**	**8,799**	**15,832**	**13,649**	**9,976**	**2,583**	**50,971**

- Hence, to complete the full DOE commitment for both the HL-LHC ATLAS and CMS detector projects, including the I&I and any technical scope, an additional **$50.97M** is needed during FY 2026-2031 through the LHC ops program

HEP Facilities and Operations







*$34M for liquid argon for DUNE FD#2 needed in 2028

Exploring the Quantum Universe

Recommendation 2

Rank-Ordered

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

a. **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.

b. **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.

c. **An off-shore Higgs factory**, realized in collaboration with international partners, in order to reveal the secrets of the Higgs boson. The current designs of FCC-ee and ILC meet our scientific requirements. The US should actively engage in feasibility and design studies. Once a specific project is deemed feasible and well-defined (see also Recommendation 6), the US should aim for a contribution at funding levels commensurate to that of the US involvement in the LHC and HL-LHC, while maintaining a healthy US on-shore program in particle physics.

d. **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.

e. **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.

DOE (along with NSF) have ended the CMB-S4 project; however, the agencies are working together to support **a modest upgrade to SPT-3G and Bicep as the South Pole Observatory (SPO)**; DOE is also planning **a modest contribution to operations at the Simon's Observatory** in Chile. These efforts together will achieve significant sensitivity to inflation signatures that the terminated CMB-S4 program proposed.

We will not consider beginning a second phase of DUNE until Phase-1 construction is nearing completion. (after 2030-31)

We have paused any consideration of a G3 dark matter project. We continue to develop a strategy for the dark matter search program.

DOE is not involved in IceCube-Gen 2.

DOE HEP must consider **what level of involvement** in the off-shore Higgs Factory that can be supported at this time.

Top Line FY25 – FY26 comparison

	FY25	FY26	FY25-26 Delta		
Total HEP + ARDAP Authorization	**1,261,570,000**	**1,235,156,000**			
ARDAP	26,860,683	27,000,000			
SBIR and SC Reserves	19,978,395	22,450,000			
Total HEP Authorization	**1,214,730,922**	**1,185,706,000**	98%	Down 2%	
Projects	423,075,000	412,400,000		Non-discretionary	
HEP after Projects	791,655,922	773,306,000	98%	Down 2%	
HEP Facility Operations	357,137,582	374,461,000	105%	Up 5%	
HEP after Projects and Operations	434,518,340	398,845,000	92%	Down 8%	This is what is left for Research

Labs	288,328,486	244,584,340	85%	Down 15%	
University Grants	144,799,427	137,400,959	95%	Down 5%	
Headquarters	1,390,427	16,859,701*			Unassigned
	434,518,340	398,845,000			

* Includes allocation for GENESIS Mission RFA

Take-aways

- Budget Formulation
  - Largely out of our hands except for compliant paperwork
  - Driven by Administration priorities
    - DOE CFO -> OMB -> DOE CFO -> SC Budget Office -> Guidance to HEP
    - Congressional appropriations determine the top line + constraints
- FY27 PBR = $1120M for HEP(+ARDAP)
- FY27 House Mark = $1260M ($49M for SURF and $15M for ACORN)
- Top down constraints require a paradigm shift in how we manage and plan our program
  - On-going projects and transition to operations consume all available budget for the next 5 years.
  - The following decade will need to produce science from HL-LHC, DUNE and Rubin, ….
  - We need to continue to pursue the search for dark matter – *do we need a better strategy?*

Some specific language from FY27 House Mark :

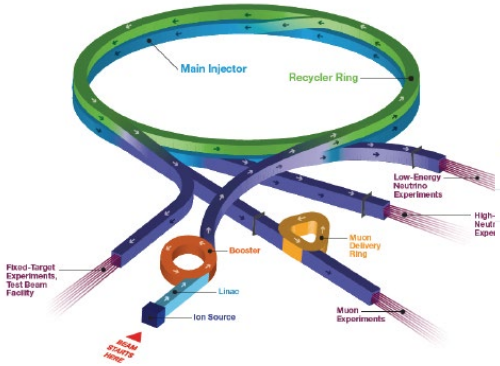
Project Management Improvements.—The Committee is concerned by significant cost growth and schedule delays affecting major projects across the Office of Science's portfolio. The Committee recognizes the Office of Science's longstanding effort to balance research, operations, and construction across its enterprise; however, large and unexpected cost increases on projects have placed increasing pressure on operations funding, threatening support for conducting new small- and medium-scale experiments and maintaining a strong level for research. The Committee directs the Office of Science to evaluate current project management processes, including cost estimation, contingency planning, and risk evaluation, and to identify opportunities to strengthen project execution across the national laboratory enterprise. The Committee expects this to be a new, enterprise-wide assessment and will not accept a response that simply summarizes its ongoing activities. Not later than 180 days after the date of enactment of this Act, the Office of Science shall provide a briefing to the Committee on its plans for evaluating, addressing, and improving risk evaluation, project management, and cost estimation for its projects.

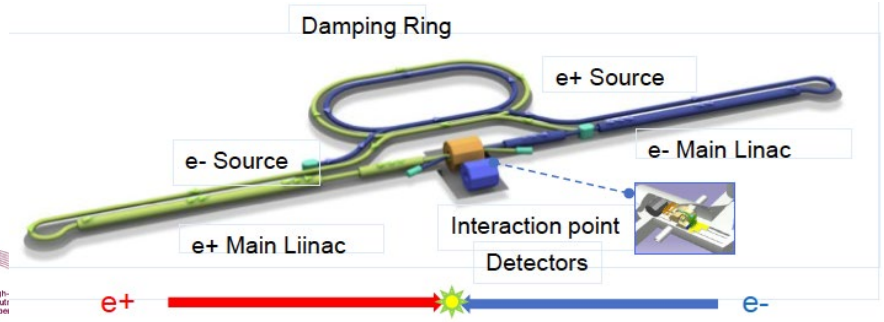
Next 5 years (2027-2031)

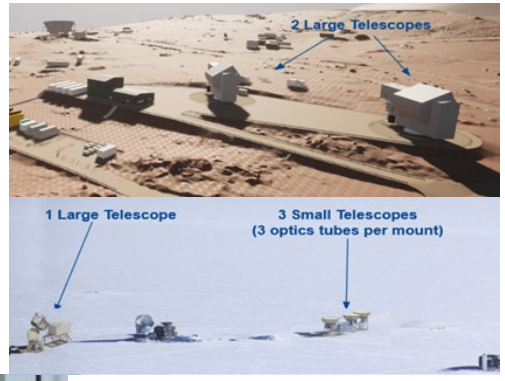
- Complete PIP-II
- Complete mu2e
- Complete ACORN
- Complete HL-LHC
- Complete LBNF/DUNE (almost)
- Upgrade and operate SPO
- Contribute to SO operations
- Operate SuperCDMS
- Update Dark Matter strategy
- Evaluate GARD program thrusts and AAC strategy
- Operate RUBIN/LSST
- Operate DESI
- Complete operations of BELLE-II (~2032)
- Complete operations of AMS (~2030)

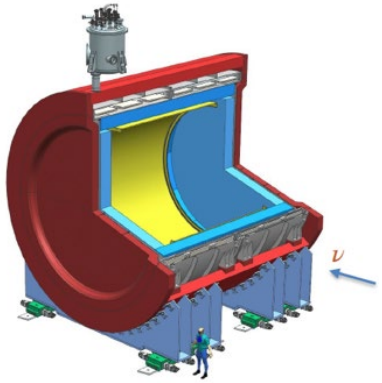
New projects ?

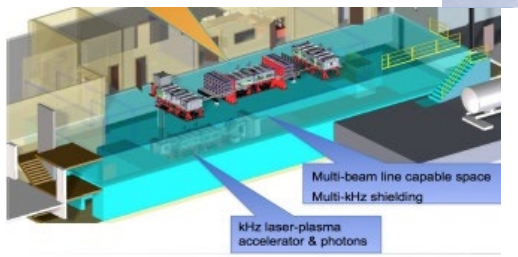
HEPAP Facilities Subpanel Report - Issued in May 2024

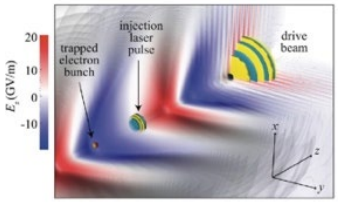


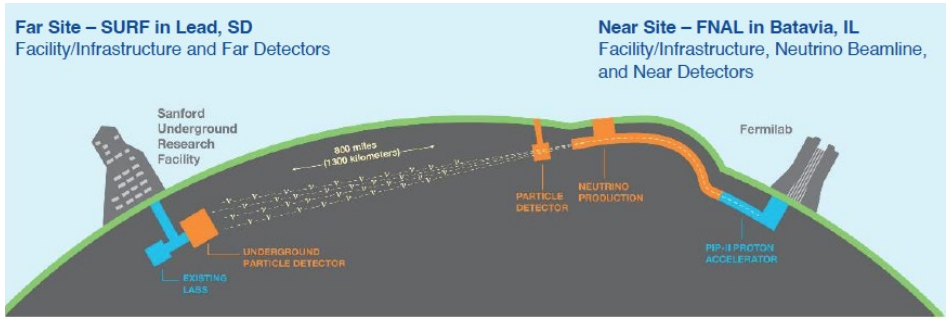


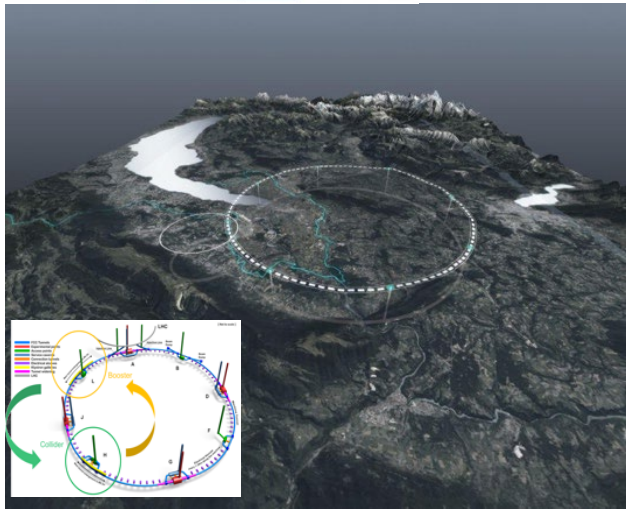


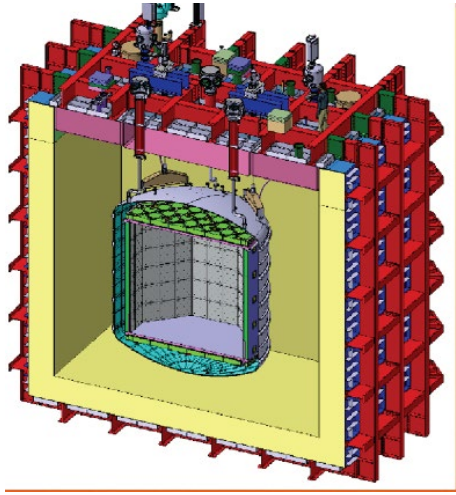


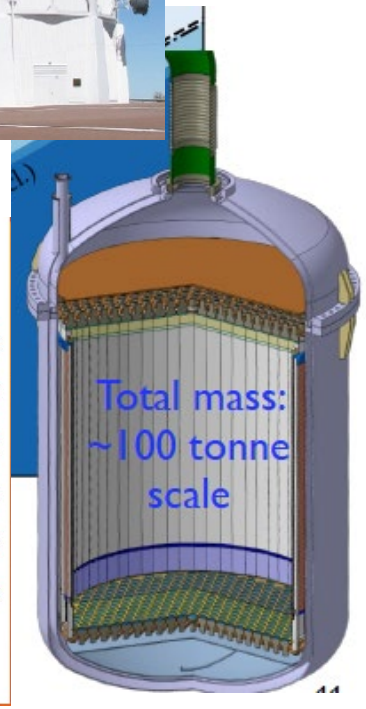












Executive Summary of HEP Facilities Report (2024)

		Science Assessment				Technical Readiness		
		Absolutely central	*Important*	*Lower priority*	*Don't know*	*Ready to initiate construction*	*Significant scientific/ engineering challenges remain*	*Mission and technical requirements not fully defined*
		A	B	C	D	A	B	C
LBNF/DUNE Phase 1		●				●		
LBNF/DUNE Phase 2	ACE-MIRT	●				●		
	FD3	●				●		
	MCND	●					●	
FD4					●			●
CMB-S4		●				●		
Spec-S5		●				●		
G3 Dark Matter		●					●	
Off-Shore Higgs Factory		●				●		
AATF - kBELLA		●					●	
ACE-BR					●			●
10 TeV pCM Collider		●						●

Office of Science Advisory Committee Charges

Facilities of the Future Charge

- Review proposed facilities and upgrades, identify any gaps, and prioritize the facilities that are most crucial to the needs of the nation for the next ten years (2026-2036)
- Consider how proposed facilities integrate with and support the Genesis Mission for AI and QIS, as well as other Administration priorities in fusion, microelectronics, biotechnology, and discovery science

AI for Transformative Science Charge

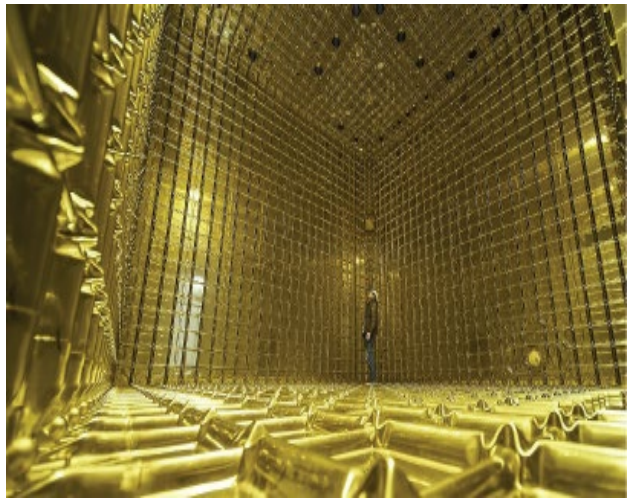
- Identify how to prioritize SC resources to accelerate the application of AI for transformative scientific and engineering discovery focused on pressing national science and technology challenges
- Create a decadal roadmap articulating near, mid, and long-term priorities for SC to achieve the Genesis Mission

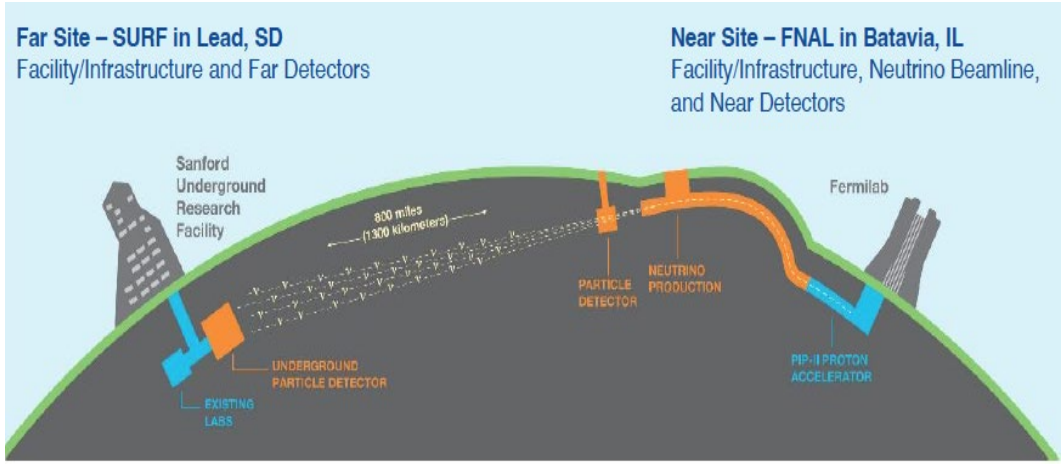
Quantum Computing Roadmap Charge

- Create a roadmap to identify near-term steps to a concrete 2028 goal of an error-corrected quantum computer capable of revolutionary science
- Assess current landscape, noting technical opportunities, gaps, and public-private partnerships to leverage impact

Deep Underground Neutrino Experiment – Phase 2 Detectors and Supporting Infrastructure

- Critical upgrades which will enable DUNE to establish whether CP violation exists in the neutrino sector.
- Three components have been proposed for a second phase of a two-part strategy for constructing the LBNF/DUNE
  - Third DUNE Far Detector (FD3)
  - Accelerator Complex Evolution Main Injector Ramp and Target (ACE-MIRT) at Fermilab
  - DUNE More Capable Near Detector (MCND)





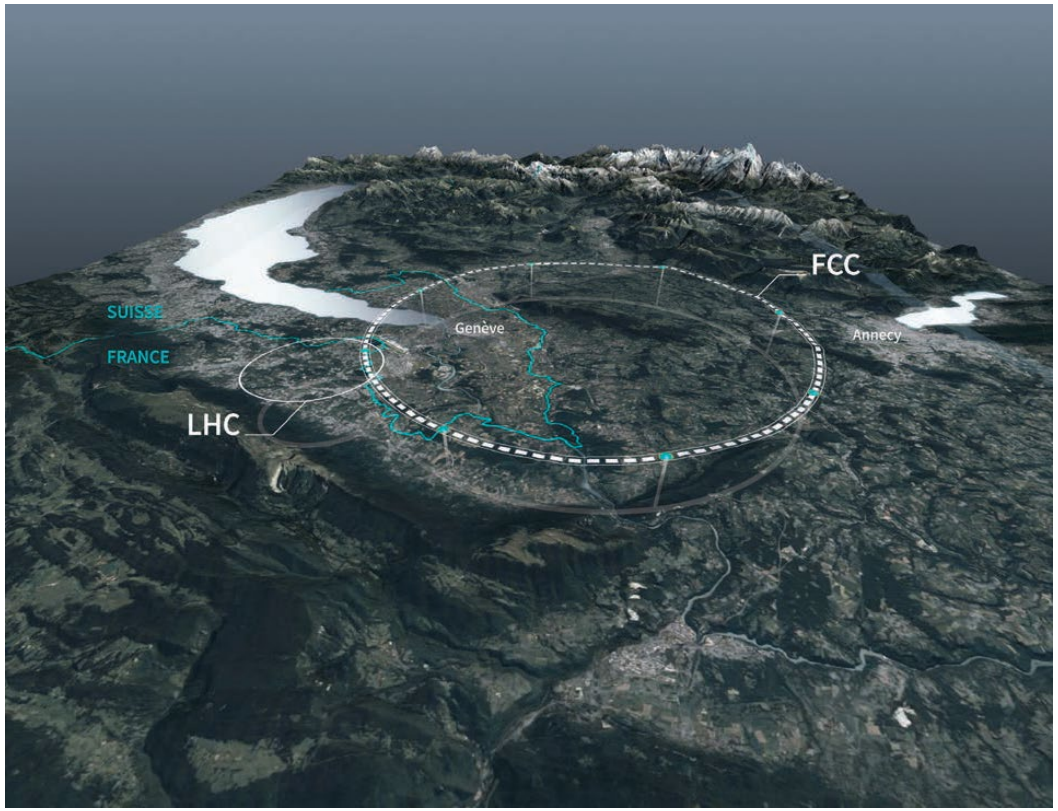
U.S. Contribution to Future Energy Frontier Collider

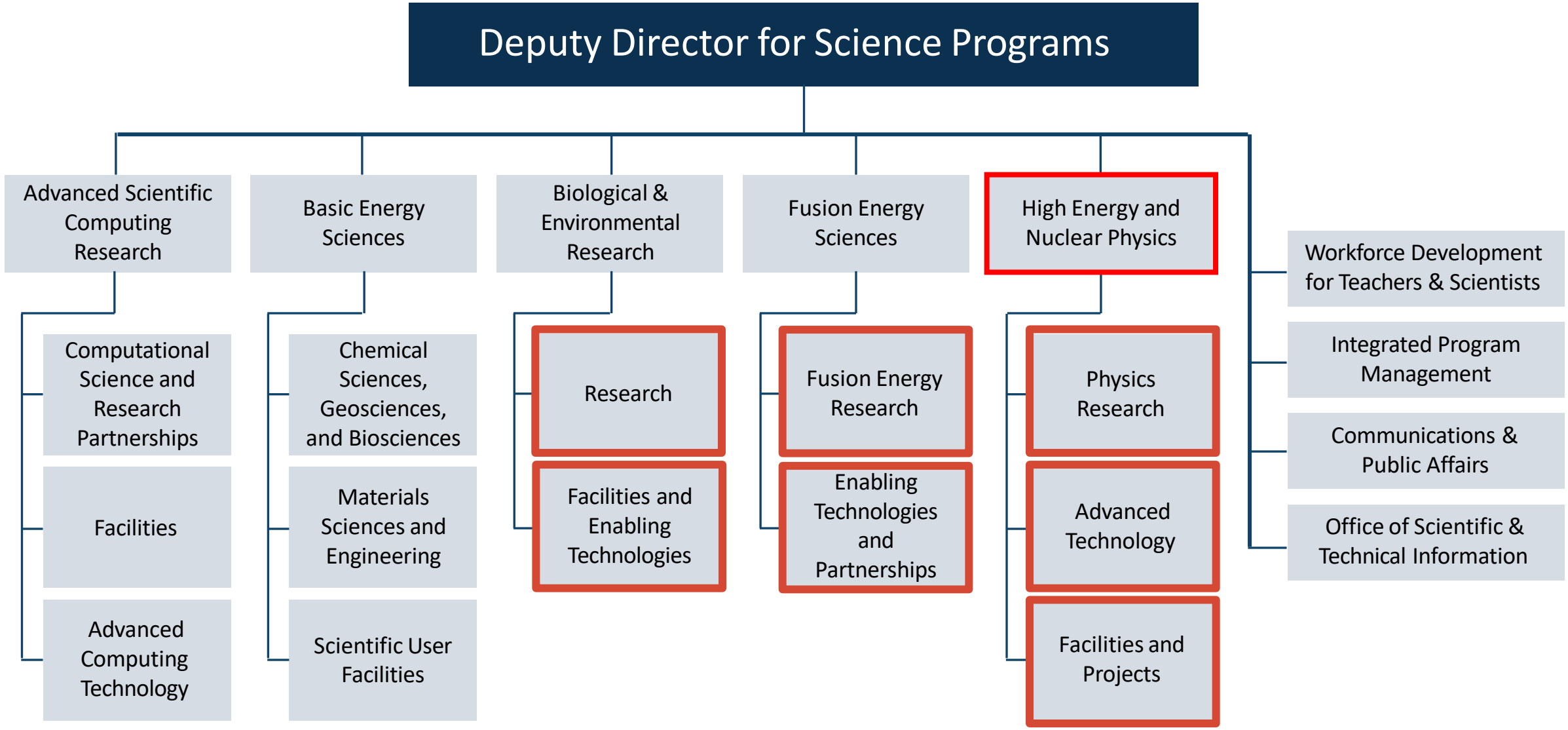
The next Energy Frontier Collider in the world is planned to be a high-energy electron-positron collider at CERN: The Higgs Factory. U.S. contributions to the particle accelerator and detector technologies that will be required for this state-of-the-art project will be critical to its success.

- The discovery of the Higgs boson at the CERN Large Hadron Collider in 2012 was a major milestone in particle physics, receiving a Nobel Prize. The next frontier is to understand the role of the Higgs with precision measurements at a dedicated Higgs Factory.

- Fundamental questions include: Is the recently discovered Higgs boson only the first one in a new family of particles? Is the Higgs boson an elementary particle or composite of smaller constituents?

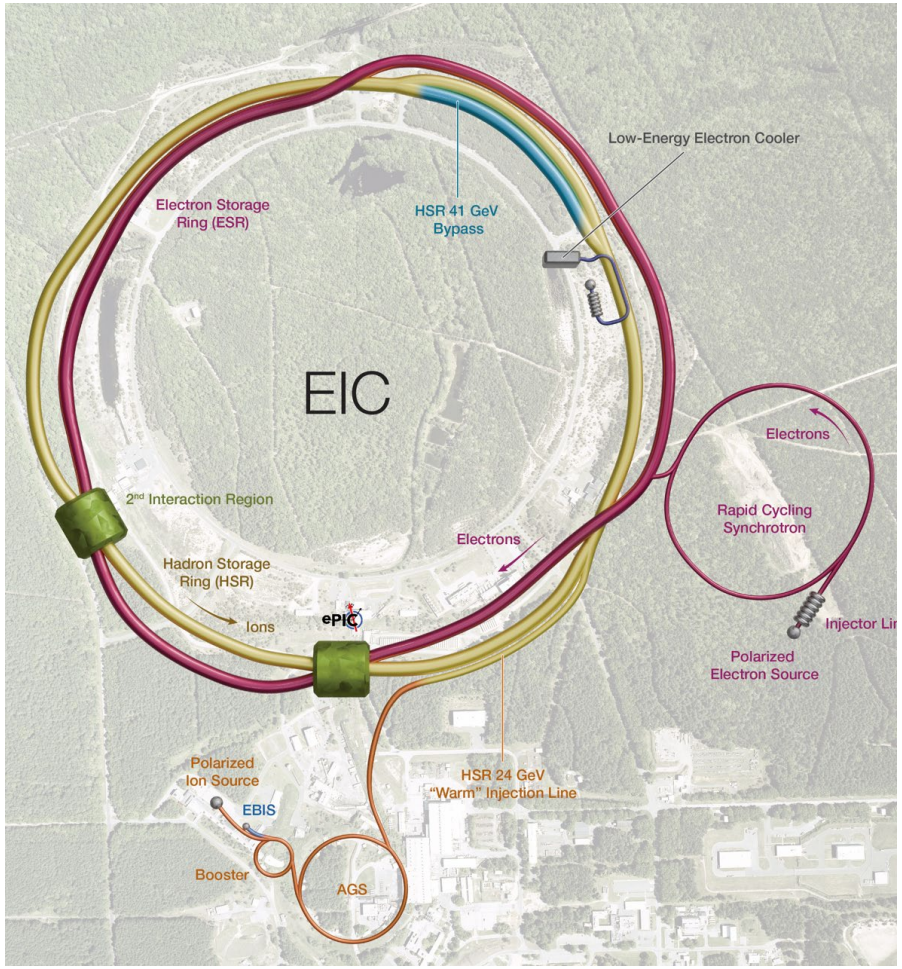
- The U.S. made key contributions to the LHC accelerator and detectors; innovations needed for the Higgs Factory will drive progress in critical technology areas such as AI and microelectronics.




Deputy Director for Science Programs
Advanced Scientific Computing Research
Basic Energy Sciences
Biological & Environmental Research
Fusion Energy Sciences
High Energy and Nuclear Physics
Workforce Development for Teachers & Scientists
Integrated Program Management
Communications & Public Affairs
Office of Scientific & Technical Information
Computational Science and Research Partnerships
Facilities
Advanced Computing Technology
Chemical Sciences, Geosciences, and Biosciences
Materials Sciences and Engineering
Scientific User Facilities
Research
Facilities and Enabling Technologies
Fusion Energy Research
Enabling Technologies and Partnerships
Physics Research
Advanced Technology
Facilities and Projects

Electron-Ion Collider: Top Priority for New Facility Construction in the Nuclear Science Long Range Plan

- Located at BNL, using existing RHIC assets, with TJNAF as a major partner.
- Estimated cost range of $1.7 billion to $2.8 billion.
- In-kind contributions: New York State and International partners
  - $100M grant from New York supports civil construction
  - ~$90M anticipated for the detector ePIC (~30%)
  - ~$50M anticipated accelerator scope (~5%)
- Critical Decision-3A (long lead procurement): March 2024
- Critical Decision CD-3B (second long lead procurement request) approved January 2026.
- Project elaborating its subproject strategy.

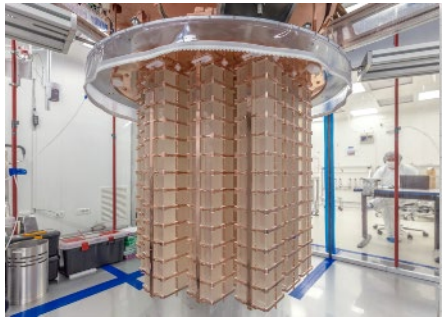


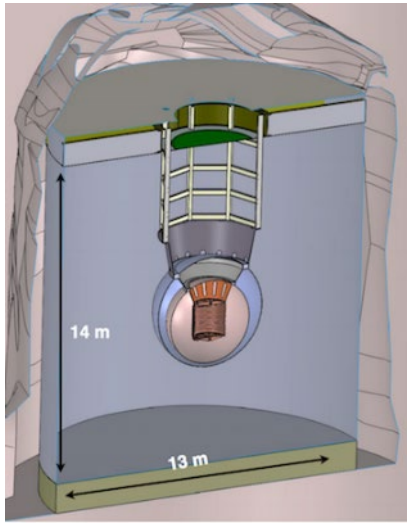
Neutrinoless Double Beta Decay: Top Priority for New Experiment Construction in the Nuclear Science Long Range Plan

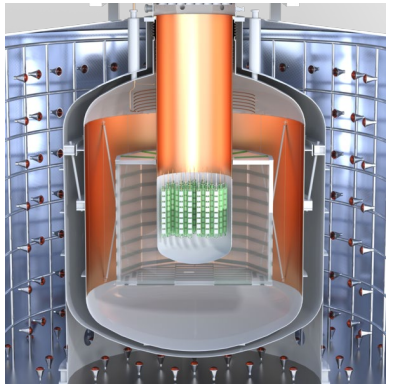
- Roughly $20.0M has been allocated since 2020 to explore three technologies: CUPID, LEGEND-1000, nEXO, and; supporting conceptual design and R&D.
- **In December 2024, LEGEND-1000 selected as the first priority for NP investment.** (est. cost $500 M)
- A multi-pronged campaign to detect neutrinoless double beta decay is an international enterprise.
- Funding agencies representatives from Canada, France, Germany, Spain, United Kingdom, and the U.S. (DOE and NSF) are working to define contributions

Three proposed technologies:

- Scintillating bolometry (CUPID, ^{100}Mo enriched Li_2Mo_4 crystals)
- **Enriched ^{76}Ge crystals (LEGEND-1000, drifted charge, point contact detectors) – 1st priority for NP support**
- Liquid Xenon TPC (nEXO, light via SiPM, drifted ionization)







Exploring the Quantum Universe

Recommendation 6

Convene a targeted panel with broad membership across particle physics later this decade that makes decisions on the US accelerator-based program at the time when major decisions concerning an offshore 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 following:

a. 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.

b. Mid- and large-scale test and demonstrator facilities in the accelerator and collider R&D portfolios.

c. A plan for the evolution of the Fermilab accelerator complex consistent with the long term vision in this report, which may commence construction in the event of a more favorable budget situation.

DOE HEP intends to generally follow this recommendation, albeit with separate panels for a and c;
It is unlikely that we initiate any new test or demonstrator projects in the next 6-7 years;
we do not plan a panel for b in the near term.