

DOE Office of Nuclear Physics Overview

Paul Mantica
Office of Nuclear Physics
June 11, 2024

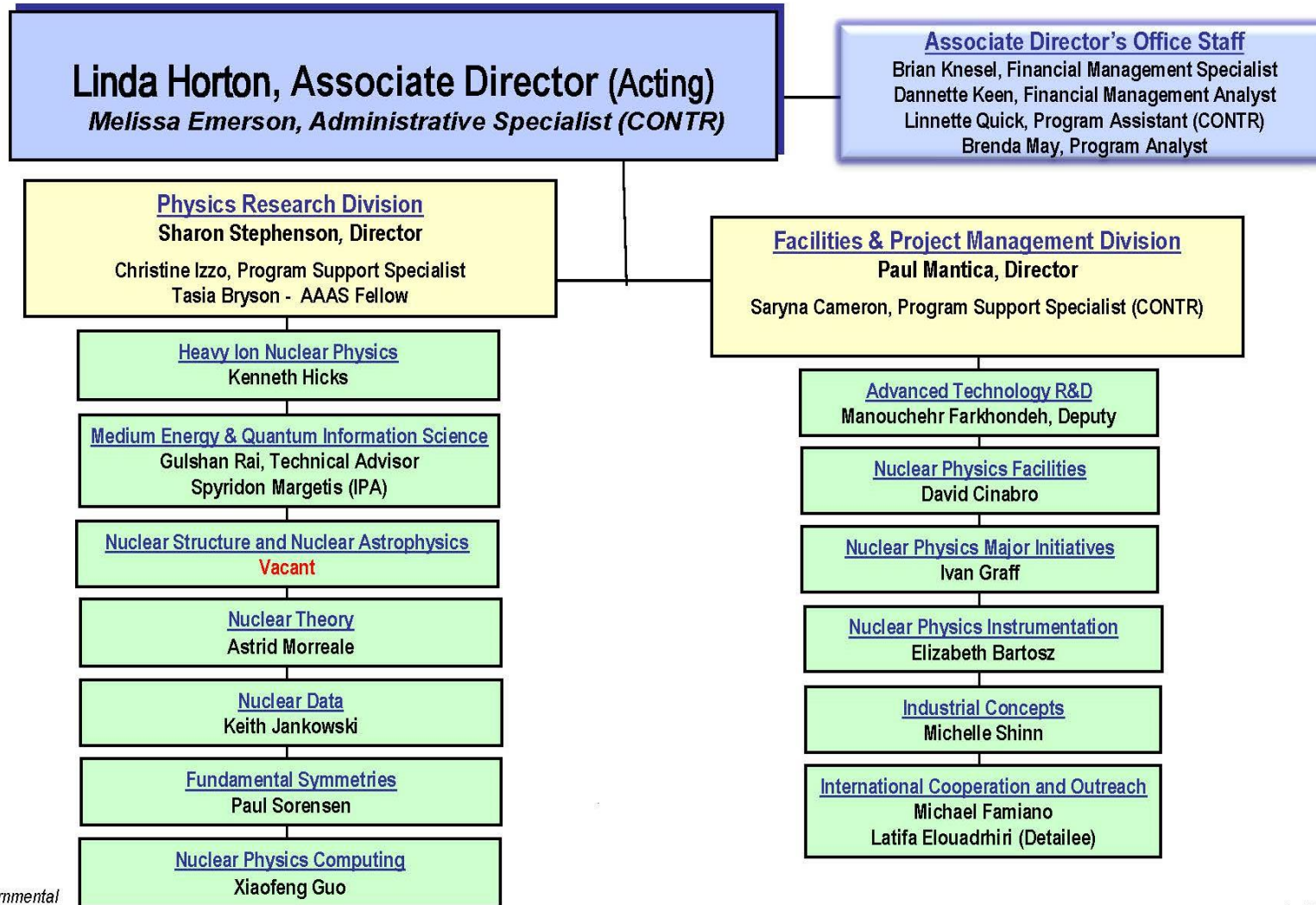


U.S. DEPARTMENT OF
ENERGY

Office of
Science

[Energy.gov/science](https://www.energy.gov/science)

DOE-SC Office of Nuclear Physics



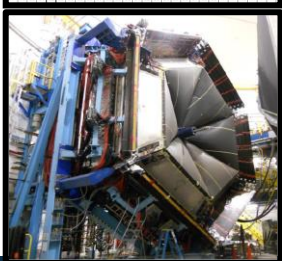
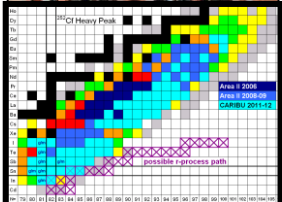
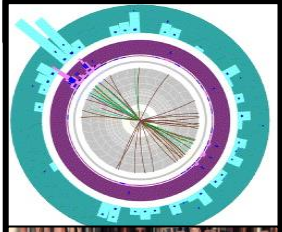
(IPA) –
Intergovernmental
Personnel Act

April 8, 2024

DOE Nuclear Physics Program

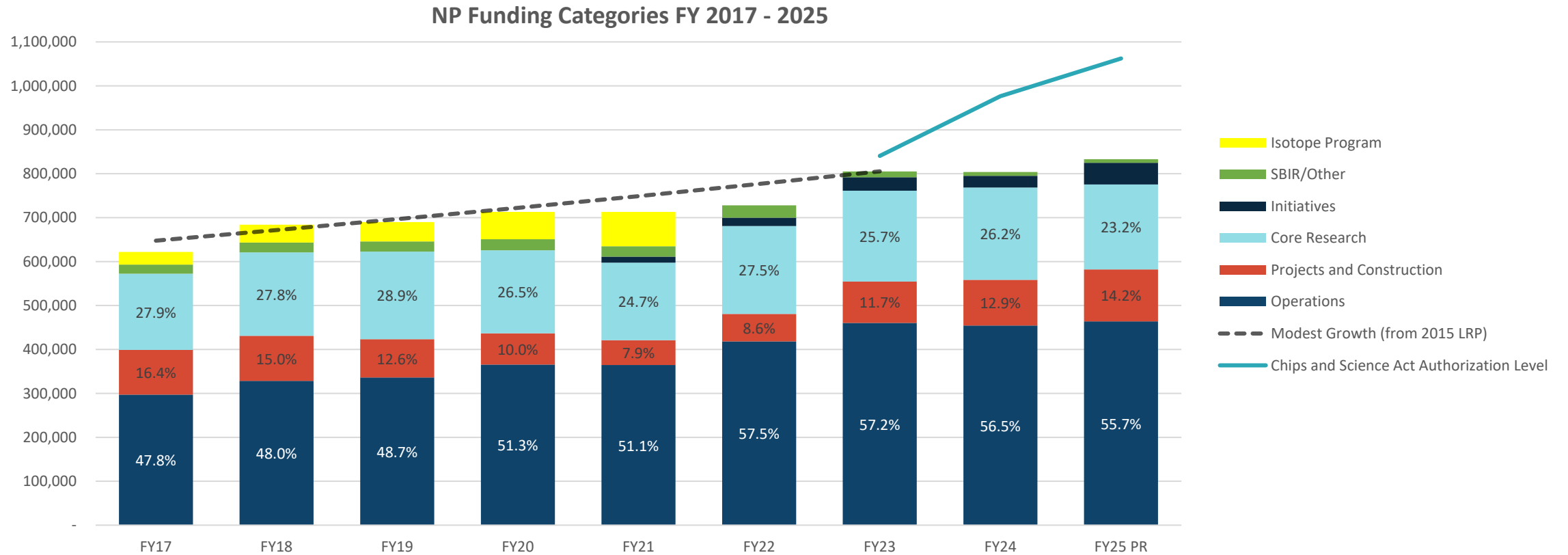
Understanding why matter takes on the specific forms observed in nature and how that knowledge can benefit energy, economic, and national security

- ◆ **Quantum Chromodynamics:** Mapping the inside of the proton; Discovering the properties of quark-gluon plasma; and Exploring mechanisms underlying confinement of quarks and gluons
- ◆ **Fundamental Symmetries:** Searching for new exotic particles and violations of nature's symmetries
- ◆ **Nuclei and Nuclear Astrophysics:** Determining the limits of nuclear existence and how heavy elements are made in stars
- ◆ **Neutrino-less Double Beta Decay:** Discovering if the neutrino is its own anti-particle or if the neutron's precise properties point to new physics
- ◆ **Nuclear Theory:** Exploring the strong force in many-body systems
- ◆ **Nuclear Data:** Curation of accurate nuclear data for space, energy, and research



The Trend in DOE-NP Appropriations

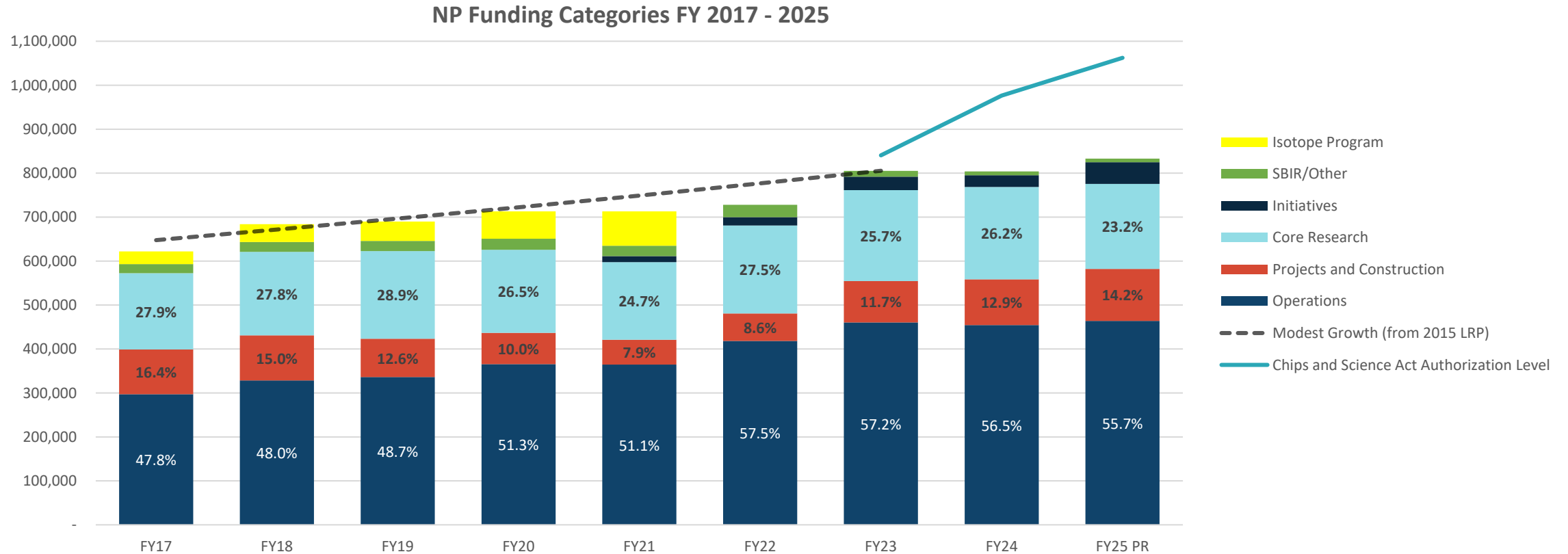
FY 2024 appropriation (\$804M) is approximately flat with FY 2023



FY 2024 supports user facility operations at ~90% of the funding level required for full operations. Increased support of construction is focused on EIC. For research, initiative support focuses on QIS, AI/ML, RENEW, FAIR. Core research is up slightly.

Trend in DOE-NP Appropriations

FY 2025 President's Budget Request is ~\$833.1M, ~3.6% above FY 2024

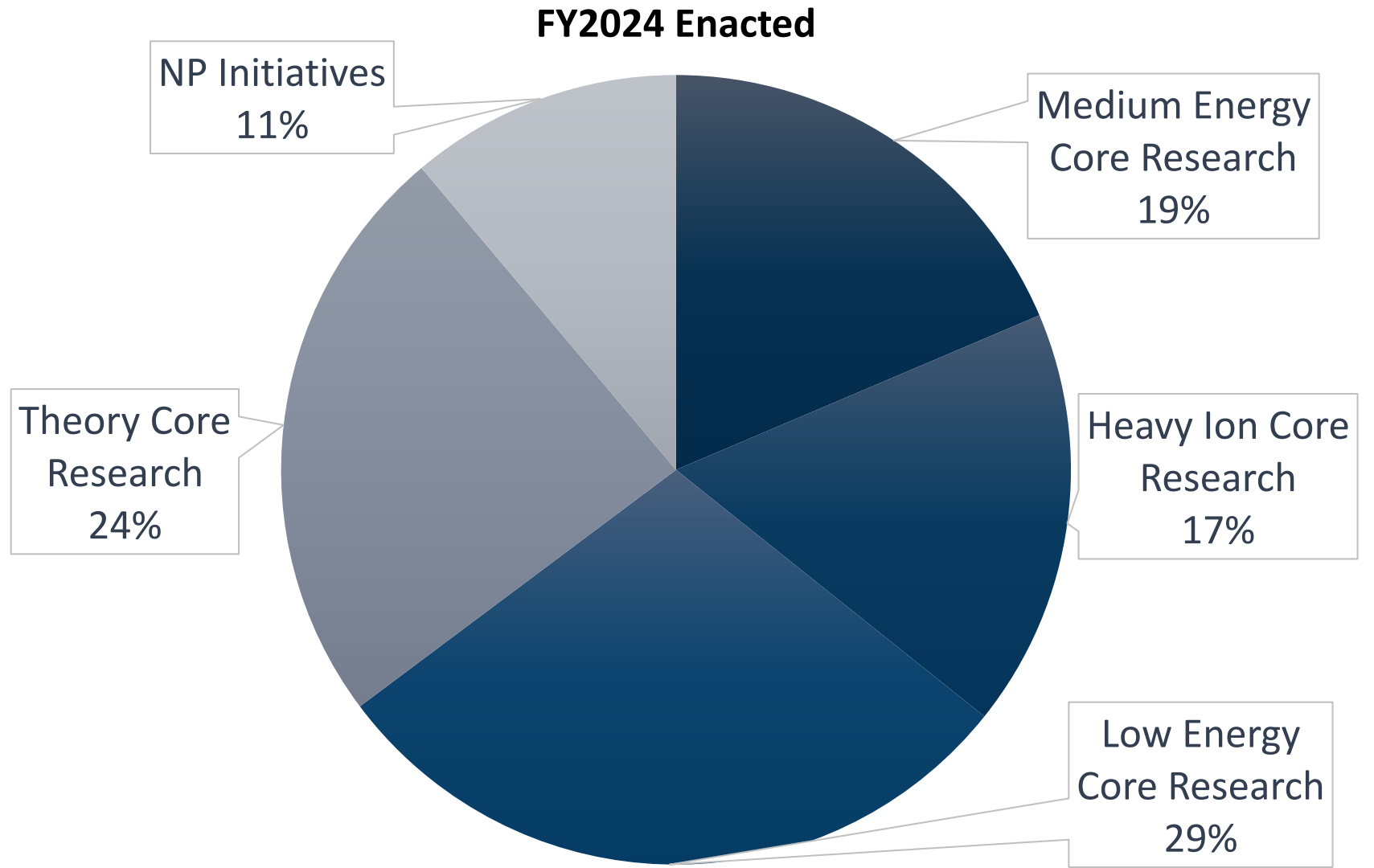


FY 2025 President's Budget Request supports user facility operations at >90% of the funding level required for full operations. Increase support for construction is focused on EIC. For research, increased initiative support (+\$23M) focuses on AI/ML, RENEW, and FAIR; Core research is down by ~\$17M.

FY 2024 NP-RD Appropriations Overview

- \$256M FY2024 Enacted

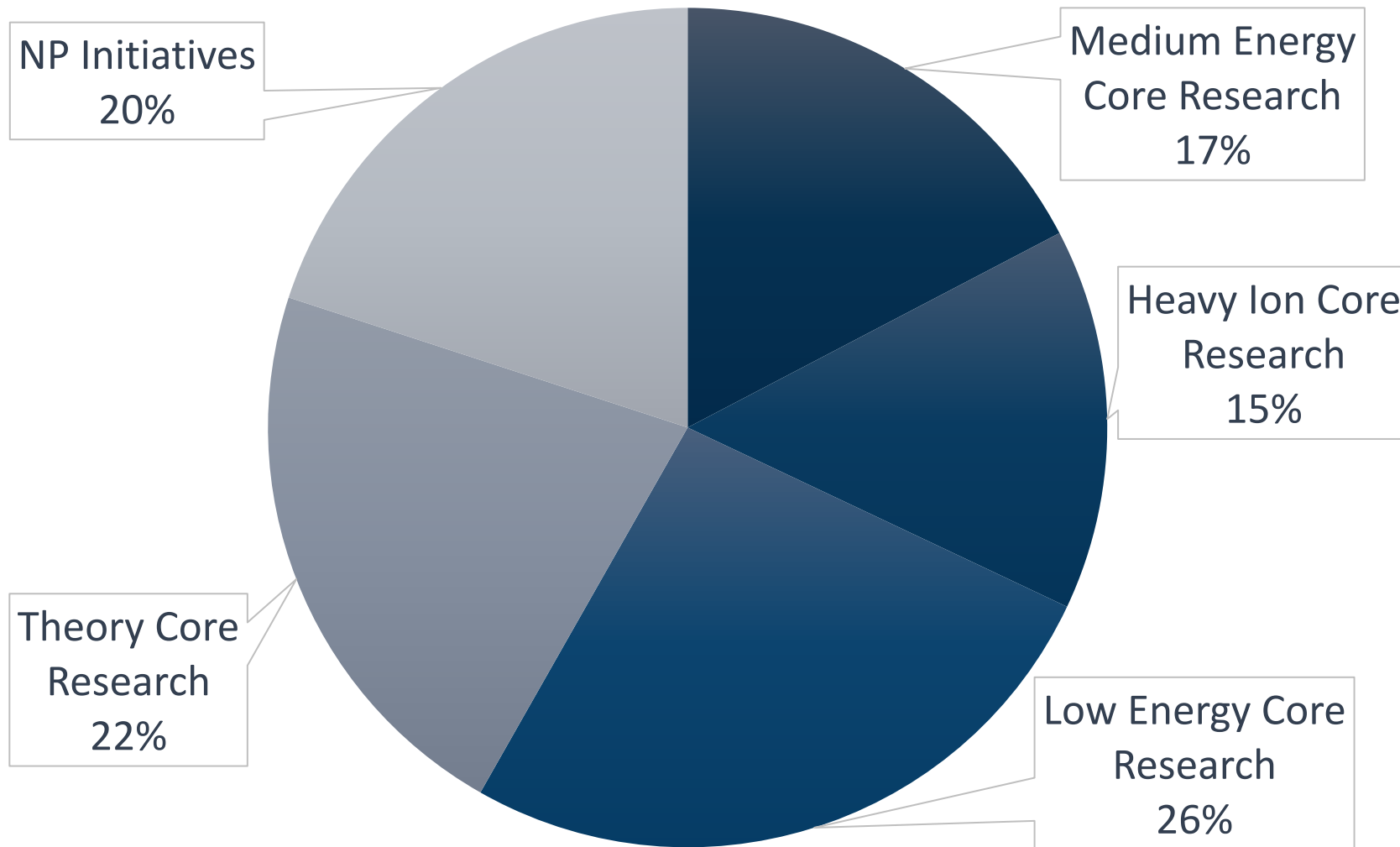
- NP Initiatives:
 - *Microelectronics*
 - *AI/ML*
 - *QIS*
 - *ACCELERATE*
 - *RENEW*
 - *FAIR*



FY 2025 NP-RD President's Budget Request Overview

FY 2025 President's Request

- \$251M FY 2025 President's Request
- Initiative investment increases (~\$23M) focus on AI/ML, RENEW, and FAIR
- Core Research will focus on highest priorities (down ~\$17M from FY 2024 Enacted)



FY 2024 Funding Opportunities/National Lab Calls

Funding Opportunity Announcement/Lab Call	Title	Release Date	Closing Date	Estimated FY 2024 Funding
FOA-SC-3176	Early Career Research Program	12/15/2023	4/25/2024	~\$8M (NP)
FOA-SC-3201	EPSCoR State-Lab Grants	12/08/2023	2/28/2024	~\$2M+
FOA-3238	Nuclear Data Interagency Working Group Research Program	1/04/2024	4/04/2024	~\$12M (NP+NNSA)
FOA-3261	Research and Development for Next Generation Nuclear Physics Accelerator Facilities	1/22/2024	3/04/2024	~\$4M+ ~\$4M (FY 2025)
FOA-SC 3207	Funding for Accelerated, Inclusive Research (FAIR)	3/12/2024	7/16/2024	~\$2M
FOA-SC 3280	Reaching a New Energy Sciences Workforce (RENEW)	3/12/2024	7/23/2024	~\$6M

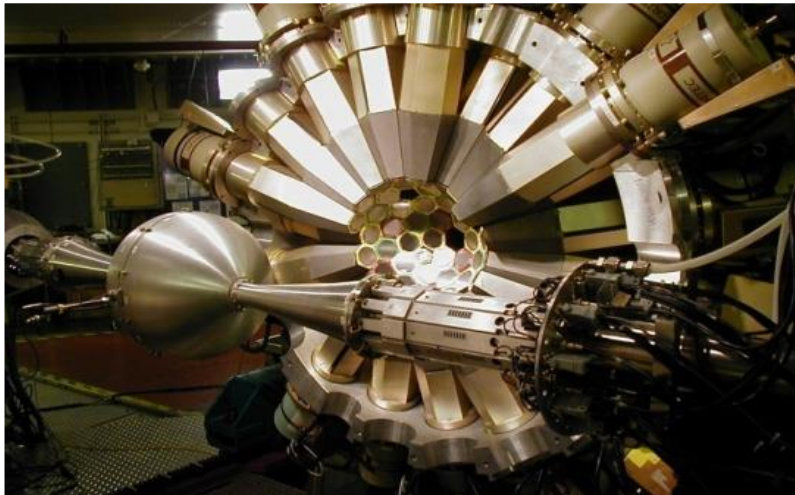
Four World-Leading National User Facilities Driving Advances



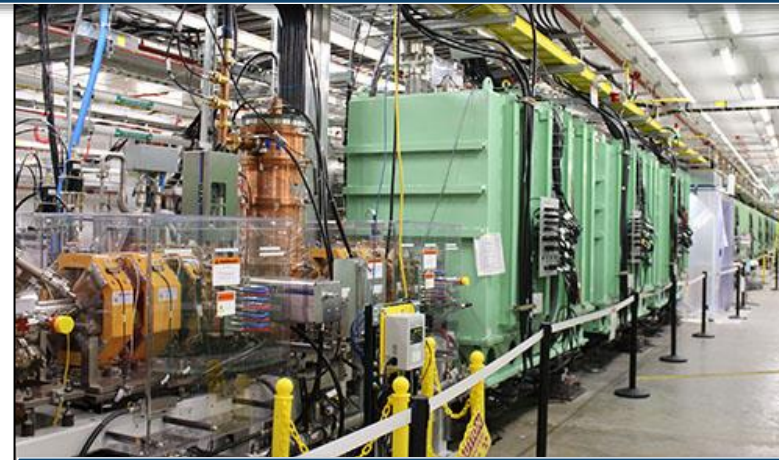
Relativistic Heavy Ion Collider



Continuous Electron Beam Accelerator Facility



Argonne Tandem Linac Accelerator System



Facility for Rare Isotope Beams

“Microscopes” with Complementary Resolving Power

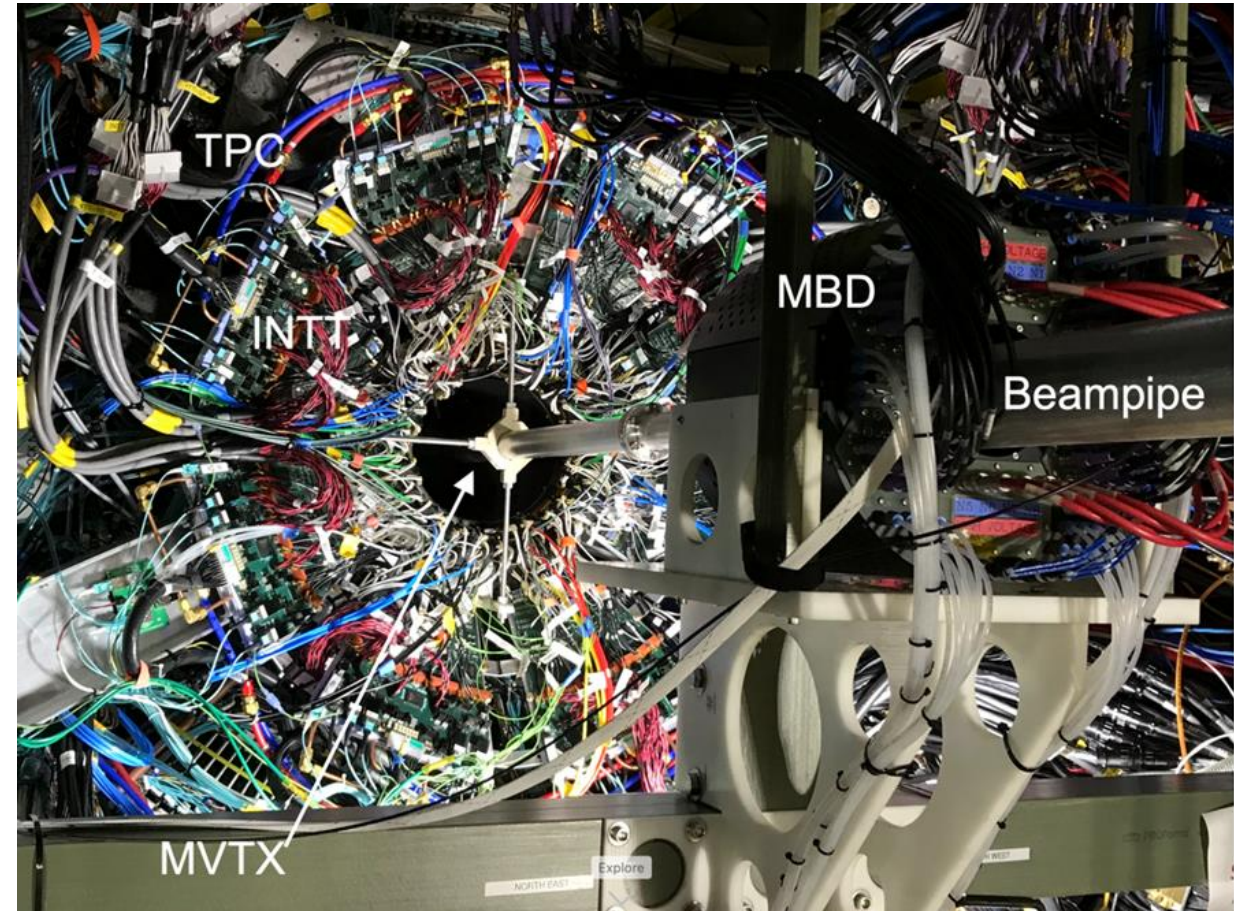
NP User Facility Operations Status

FY 2023 Enacted	FY 2024 Enacted	FY 2025 PR
<p>All NP user facilities operate at >90% of optimal funding in FY 2023.</p> <ul style="list-style-type: none"> ◆ RHIC operates 25 weeks (96% optimal) ◆ CEBAF operates 33 weeks (96% optimal) ◆ ATLAS operates 40 weeks (96% optimal) ◆ FRIB operates 26 weeks (99% of optimal) 	<p>All NP user facilities operate at roughly 90% of optimal funding in FY 2024.</p> <ul style="list-style-type: none"> ◆ RHIC supported for 19 weeks (94% optimal) ◆ CEBAF operates 27 weeks (88% optimal) ◆ ATLAS operates 39 weeks (91% optimal) ◆ FRIB operates 24 weeks (94% optimal) 	<p>All NP user facilities operate at roughly 90% of optimal funding in FY 2025.</p> <ul style="list-style-type: none"> ◆ RHIC operates 22 weeks (95% optimal) ◆ CEBAF operates 25 weeks (89% optimal) ◆ ATLAS operates 40 weeks (90% optimal) ◆ FRIB operates 26 weeks (90% of optimal)

- ◆ RHIC is planning to run 25 weeks (including 6 additional weeks due to early end of Run 23) in FY 2024 focused on p+p data for sPHENIX and STAR
- ◆ CEBAF ran 30 weeks in FY 2024 (SAD started May 21); 3 additional weeks were added with the aim to complete experiments scheduled in Hall A
- ◆ ATLAS is planning to run 39 weeks in FY 2024; readying GRETINA experiments and commissioning the nuCARIBU driver cyclotron
- ◆ FRIB is planning to run 24 weeks in FY 2024, operating at 10 kW

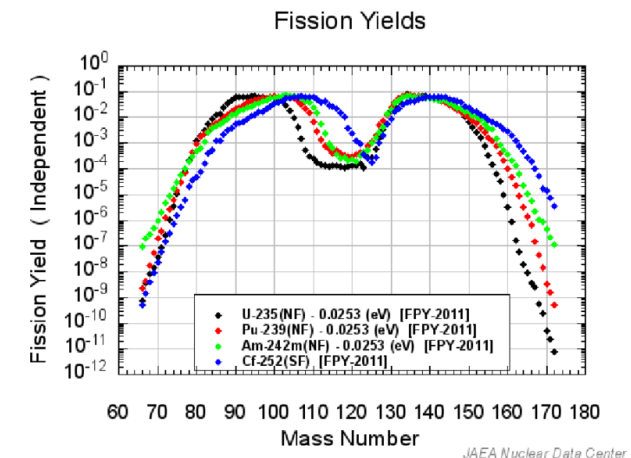
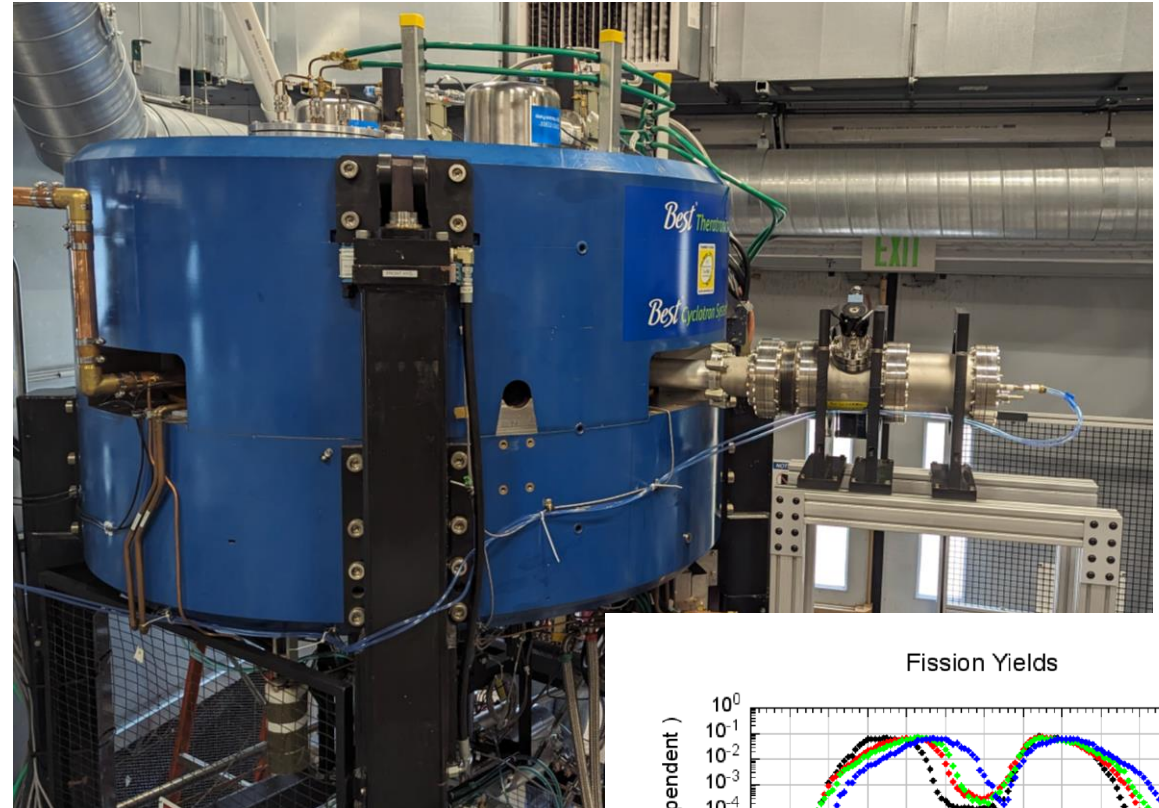
sPHENIX at RHIC

- ◆ sPHENIX is a large-acceptance, high-rate detector optimized to measure jet and heavy quark physics in heavy-ion collisions
- ◆ Construction was completed in April 2023, and commissioning activities were underway during Run 23 until a cryogenic event disrupted operations on August 1, 2023.
- ◆ Run 24 collisions were initiated in late April 2024.
 - sPHENIX (and START) now taking p+p collisions with polarized protons
 - Optimizing of luminosity and polarization
- ◆ Run 25 will focus on Au+Au collisions to complete the RHIC science mission



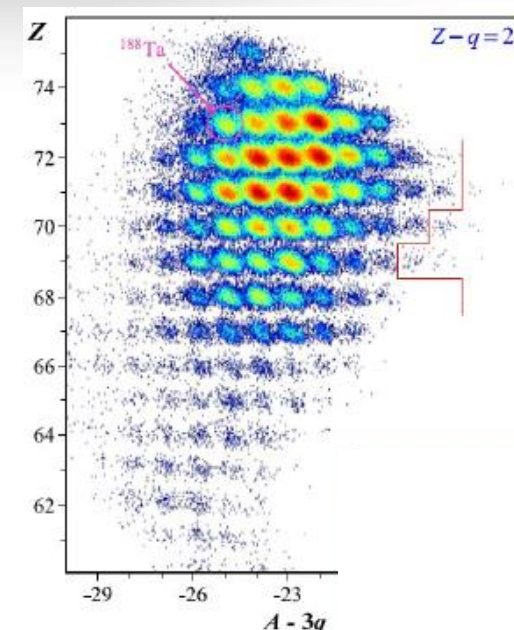
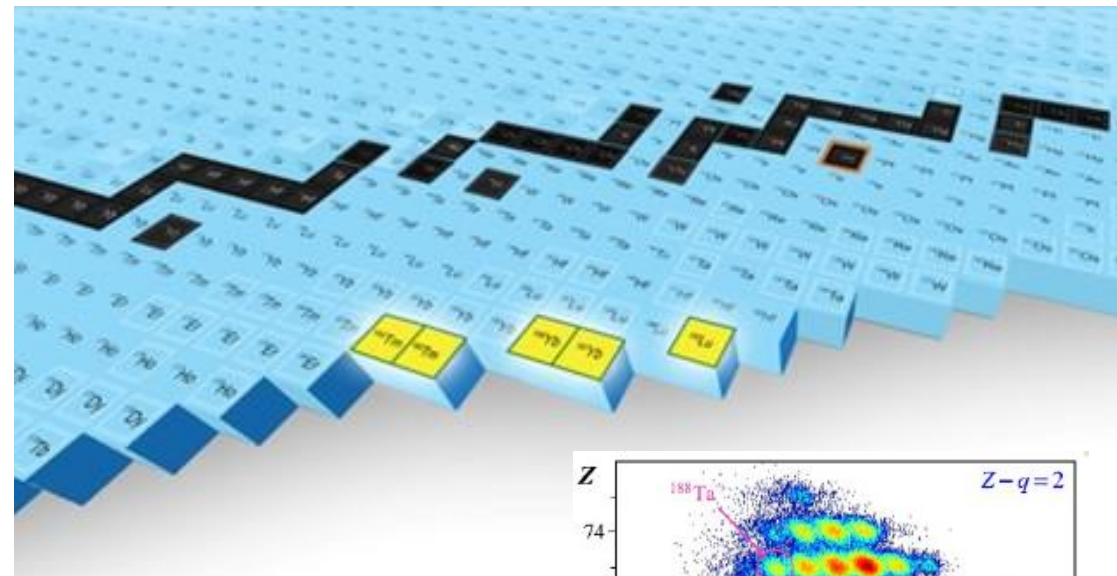
nuCARIBU at ATLAS

- ◆ ATLAS has been using a californium-252 source coupled to a gas cell (CARIBU) to provide neutron-rich fission products for low-energy nuclear physics
- ◆ nuCARIBU replaces the fission source with a commercial proton cyclotron that will be used to trigger neutron-induced fission on uranium-235
- ◆ The commercial cyclotron is undergoing commissioning
- ◆ Goal is to demonstrate extraction of barium-143 before the end of FY 2024
- ◆ Science program envisioned using both stopped and reaccelerated fission products



New Isotope Production at FRIB

- ◆ Five new isotopes of thulium, ytterbium, and lutetium were formed in the fragmentation of platinum-198 on a carbon target at 1.5 kW beam power
 - thulium-182 and 183;
 - ytterbium-186 and 187; and,
 - lutetium-190
- ◆ The new isotopes were identified in the advanced rare isotope separator (ARIS) using energy loss, time-of-flight, magnetic rigidity, and total kinetic energy data
- ◆ The results show that there are no barriers for producing, separating, and identifying the heavy neutron-rich isotopes in the region of the nuclear chart relevant for heavy-element nucleosynthesis
- ◆ FRIB is operating routinely at 10 kW beam power, with plans to increase beam power to 20 kW during FY 2025

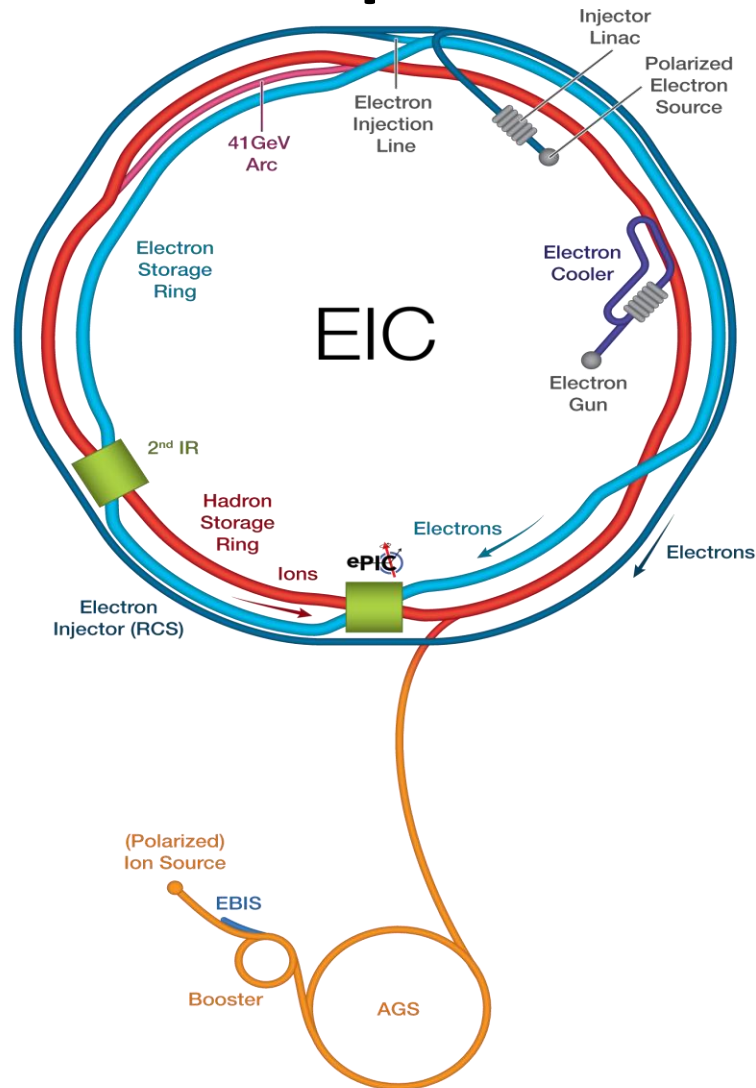


NP Projects Status

Project	Location	Status	Cost	CD-4
Construction Projects				
Electron-Ion Collider (EIC)	BNL	CD-3A	\$1.7B to \$2.8B (Est)	Q4 FY33 (Est)
Major Items of Equipment				
Gamma Ray Energy Tracking Array (GRETA) ^{FF}	LBNL	CD-2/3	\$58.3M (TPC)	3/2028
Measurement of Lepton-Lepton Electroweak Reactions (MOLLER) ^{FF}	TJNAF	CD-2/3	\$48.66M (TPC)	Q4 FY28
High Rigidity Spectrometer (HRS)	MSU	CD-1	\$85.0M to \$111.4M (Est)	Q2 FY29 (Est)
Ton Scale Neutrinoless Double Beta Decay (TS-NLDBD) Program	TBD	CD-0	\$215M to \$250M (Est)	TBD

FY 2023 Enacted	FY 2024 Enacted	FY 2025 PR
EIC at TEC of \$50M and OPC of \$20M GRETA at optimal level, providing the project with the final year of funding (\$15.5M) MOLLER receives the final \$4M of planned TEC funding TS-NLDBD at \$1.44M TEC HRS at \$3M TEC	EIC at TEC of \$95M and OPC of \$2.9M GRETA and MOLLER received full TPC amount in FY23 Request. Progress continues, but no new funding requested in FY24. TS-NLDBD at \$3M TEC HRS at \$3M TEC	EIC at TEC of \$110M and OPC of \$2.9M GRETA and MOLLER received full TPC amount in FY23 Request. Progress continues, but no new funding requested in FY25. TS-NLDBD at \$2M TEC HRS at \$3.3M TEC

Top Priority for Facility Construction in the 2023 Long Range Plan: Expedient Completion of the Electron-Ion Collider



The EIC will be the most advanced accelerator in the world and the only new collider built for decades. It will maintain US leadership in accelerator physics.

Status:

- CD-3A approved March 2024
 - ~\$90M in procurements to reduce technical risk
- Project continues to support preliminary engineering & design and execution of long lead procurements
- Pursuing additional long lead procurements (CD-3B) followed by CD-2

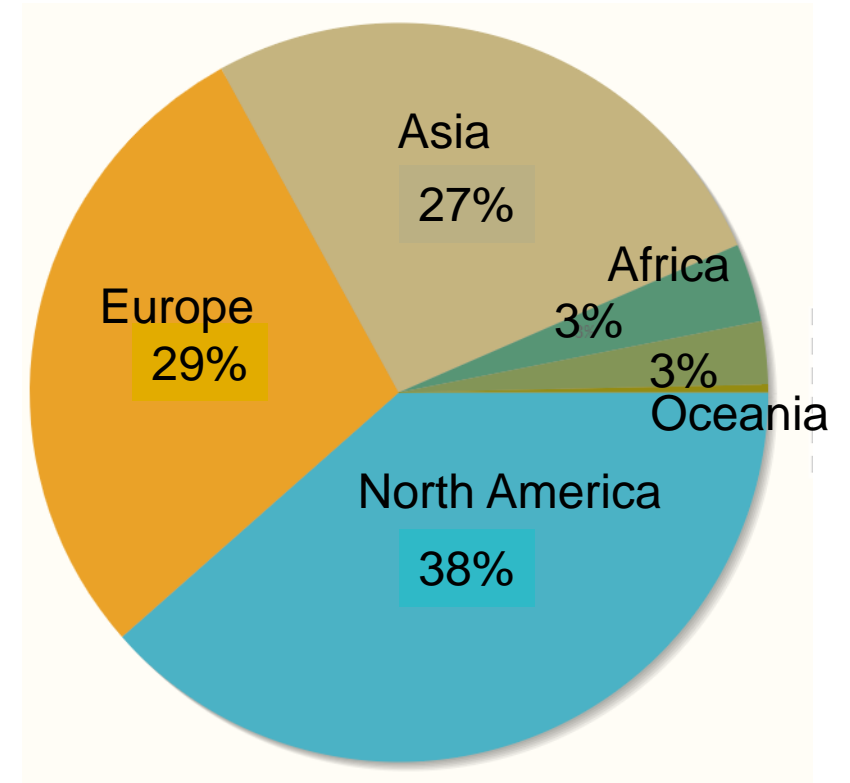
The Electron-Ion Collider is International at its Core

EIC Users Group Formed in 2016

EICUG.ORG

Status June 2024:

- ◆ Collaborators **1529**
- ◆ Institutions **294**
- ◆ Countries **40**



International Contributions to the Electron-Ion Collider

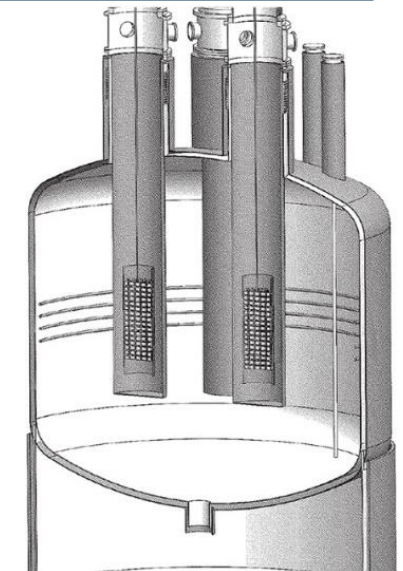
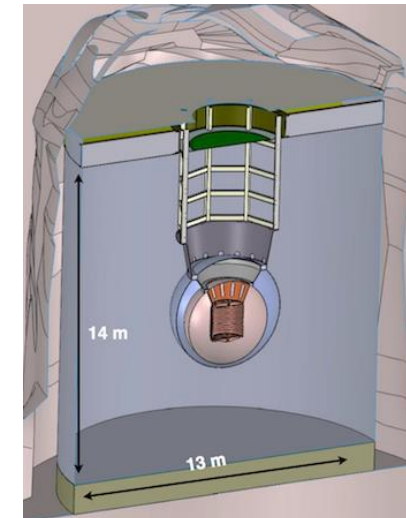
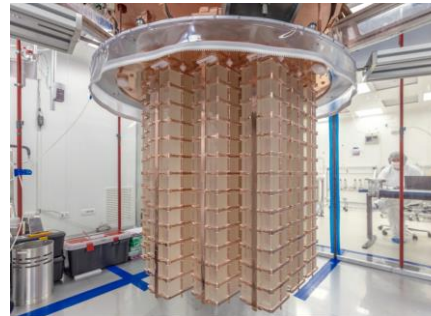
- ◆ The EIC Project is envisioning international contributions to the EIC detector of approximately \$100M, and contributions to the accelerator of approximately \$50M
 - 100% of these contributions have been notionally identified by international partners and interest continues to grow
- ◆ Two entities established to coordinate EIC in-kind contributions
 - EIC Advisory Board – Meets quarterly and provides guidance and advice to the BNL Director on the design and construction of the EIC accelerator facility and on the efforts to establish partnerships with institutions collaborating on the facility
 - EIC Resource Review Board (RRB) – Meets twice per year and provides coordination among the different funding partners during both the detector development and construction phase of the project and during the operations of the experiments that follow

Top Priority for New Experiment Construction in the 2023 Long Range Plan for Nuclear Science: Neutrinoless Double Beta Decay

- ◆ Between IRA funding and NP Program Funding, ~\$20M has been allocated since 2020 to explore three technologies: LEGEND 1000, nEXO, and CUPID; supporting conceptual design and R&D
- ◆ Additional resources provided by international partners
- ◆ Inability to procure isotopes from countries of concern is having a severe impact
- ◆ A 3rd DBD international summit is being planned for spring 2025
- ◆ A working group has been established and charged with defining an organizational framework for a Virtual Global DBD Observatory

Three Proposed Technologies

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



Potential Partners:
Italy, Canada, and Germany

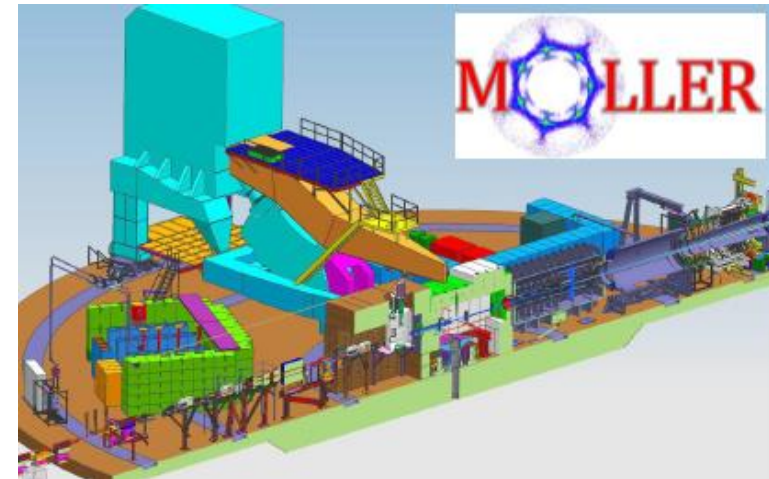
Status of other MIE Projects

Gamma Ray Energy Tracking Array (GRETA)



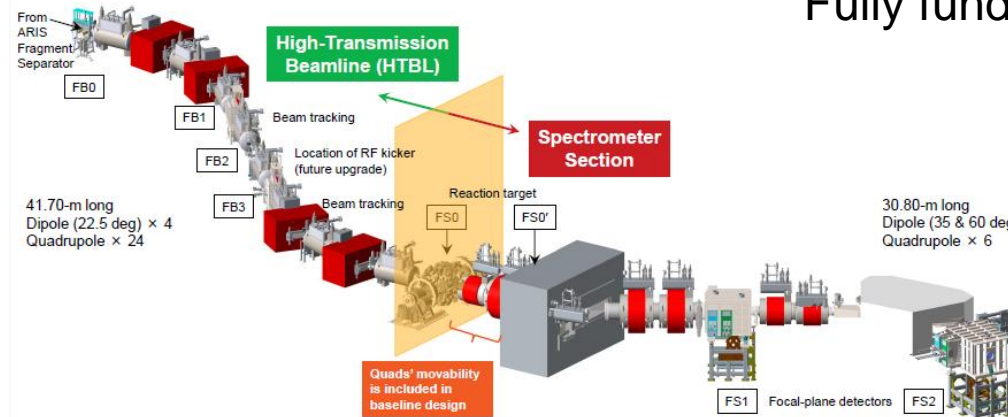
Fully funded; CD-4A forecast: Q3 FY 2025

Measurement of a Lepton-Lepton Electroweak Reaction (MOLLER)



Fully funded; CD-4 forecast: Q4 FY 2028

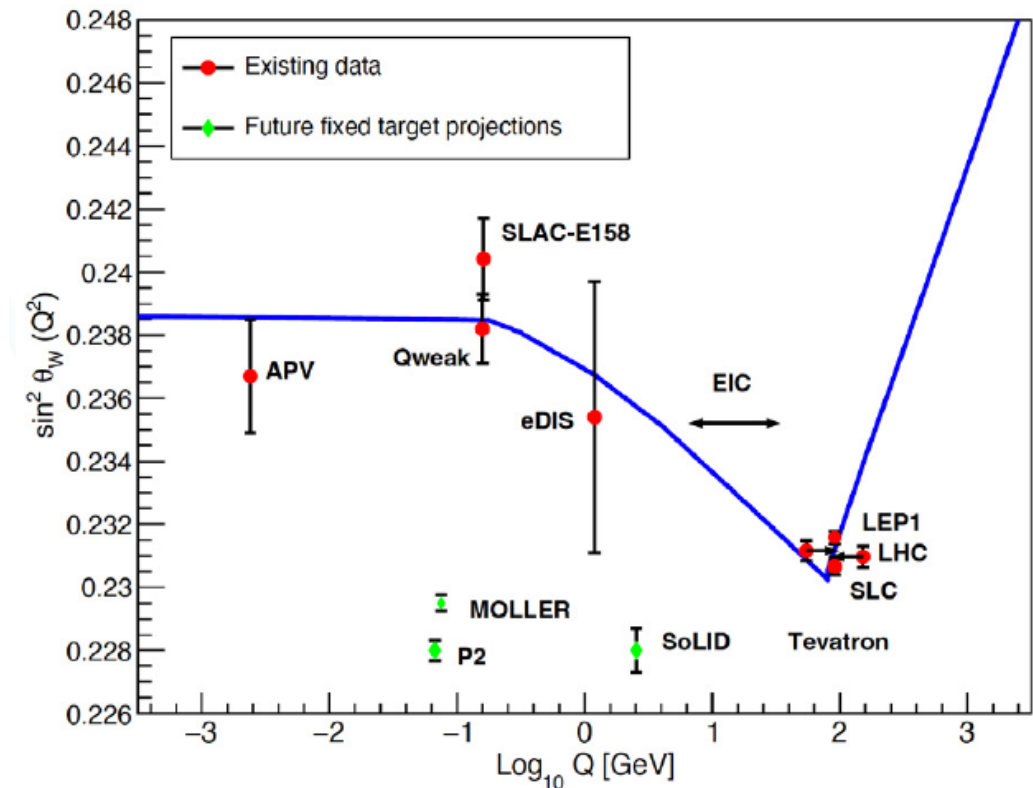
High Rigidity Spectrometer (HRS)



High-Transmission Beamline
CD-2/3 forecast: Q1 FY 2025

MOLLER Achieves CD-2/3

- ◆ The MOLLER major item of equipment received CD-2/3 approval from the Project Management Executive on May 28, 2024
 - Critical Decision-2 “Approve Performance Baseline”
 - Critical Decision-3 “Approve Start of Construction”
- ◆ MOLLER will enable CEBAF to perform the most precise measurement to date of the parity violating asymmetry, APV, in electron-electron scattering, and thus the weak charge of the electron
- ◆ In-kind contributions to MOLLER from:
 - National Science Foundation
 - Canadian Foundation for Innovation
 - Research Manitoba



The New NP Long Range Plan: A New Era of Discovery

Capitalize on the extraordinary opportunities for scientific discovery made possible by the substantial and sustained investments of the United States. We must draw on the talents of all in the nation to achieve this goal.

We reaffirm the exceptionally high priority of the following two investments in new capabilities for nuclear physics. The Electron–Ion Collider (EIC), ...will elucidate the origin of visible matter in the universe and significantly advance accelerator technology... Neutrinoless double beta decay experiments have the potential to dramatically change our understanding of the physical laws governing the universe.

As the highest priority for new experiment construction..., lead an international consortium that will undertake a neutrinoless double beta decay campaign.

We recommend the expeditious completion of the EIC as the highest priority for facility construction.

Capitalize on the unique ways nuclear physics can advance discovery science and applications for society.



NSAC Facilities Charge: Assessment of Science Importance and Readiness for Construction for NP Projects (pre-CD-2, >\$100M)

List of projects provided by NP for consideration by the subcommittee:

- ◆ Electron-Ion Collider (EIC)
- ◆ High Rigidity Spectrometer (HRS)
- ◆ Ton Scale Neutrinoless Double Beta Decay (TS-NLDBD)
 - Large Enriched Germanium Experiment for NLDBD (LEGEND-1000)
 - Next Enriched Xenon Observatory (nEXO)
 - Cryogenic Underground Observatory for Rare Events with Particle Identification (CUPID)
- ◆ Project 8
- ◆ FRIB Energy Upgrade (FRIB400)
- ◆ Solenoid Large Intensity Device (SoLID)
- ◆ EIC Detector II

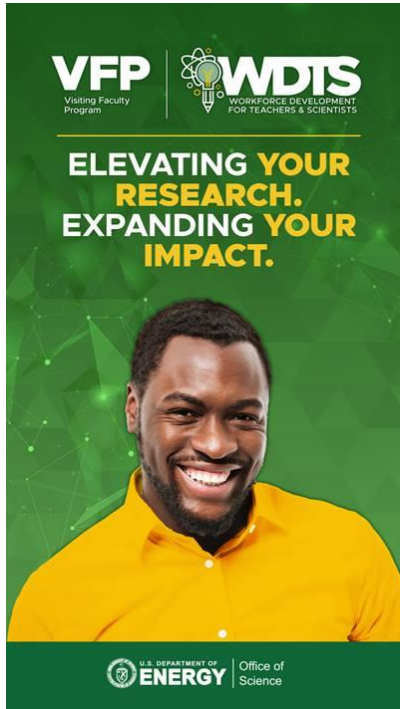
NSAC Facilities Charge Outcome

Major Nuclear Physics Facility	Scientific importance	Readiness for construction
Electron-Ion Collider (EIC)	(a) Absolutely central	(a) Ready to initiate
High Rigidity Spectrometer (HRS)	(b) Important	(a) Ready to initiate
Ton-scale Neutrinoless Double Beta Decay (TS-NLDBD)	(a) Absolutely central	(a) Ready to initiate
Project 8	(b) Important	(c) Mission and technical requirements not yet fully defined
FRIB Energy Upgrade (FRIB400)	(b) Important	(a) Ready to initiate
Solenoid Large Intensity Device (SoLID)	(b) Important	(a) Ready to initiate
EIC Detector II	(b) Important	(c) Mission and technical requirements not yet fully defined

- The importance of the science for each project as assessed by the Subcommittee was tied closely to the 2023 LRP
- In considering the readiness for construction the Subcommittee was guided by the current status of the project and remaining challenges, including the DOE critical decision level, if any.

Engagement Opportunities

<https://science.osti.gov/wdts/vfp>



Summer 10-week program. Option of inviting up to two students (one may be a graduate student). Follow on program for fall/spring term with teaching relief



Paid 10-week summer internship (May–August) or in 10-week internship during the semester (August–December or January–May)



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Office of Science Graduate Student Research (SCGSR) Program

Supplemental awards to U.S. graduate students (US citizens or lawful permanent residents) to pursue part of their doctoral research at a DOE laboratory/facility in areas that address scientific challenges central to the Office of Science mission.

Summary

- ◆ The NP mission is to discover, explore, and understand all forms of nuclear matter.
- ◆ Resources are provided to advance activities in both experimental and theoretical research in nuclear physics
 - The FY 2024 appropriation is essentially flat with FY 2024
 - The FY 2025 President's Request is 3.6% above FY 2024
- ◆ NP is working to implement the aspirations of the community in 2023 NSAC Long Range Plan within the constraints of annual appropriations
- ◆ NP is awaiting SC leadership assessment of the NSAC subcommittee report responding to the Facilities Charge
- ◆ NP along with the Office of Science is committed to advancing belonging, accessibility, justice, equity, diversity, and inclusion across the portfolio of activities we sponsor