

DOE Office of Nuclear Physics Overview

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Office of Nuclear Physics
June 13, 2024

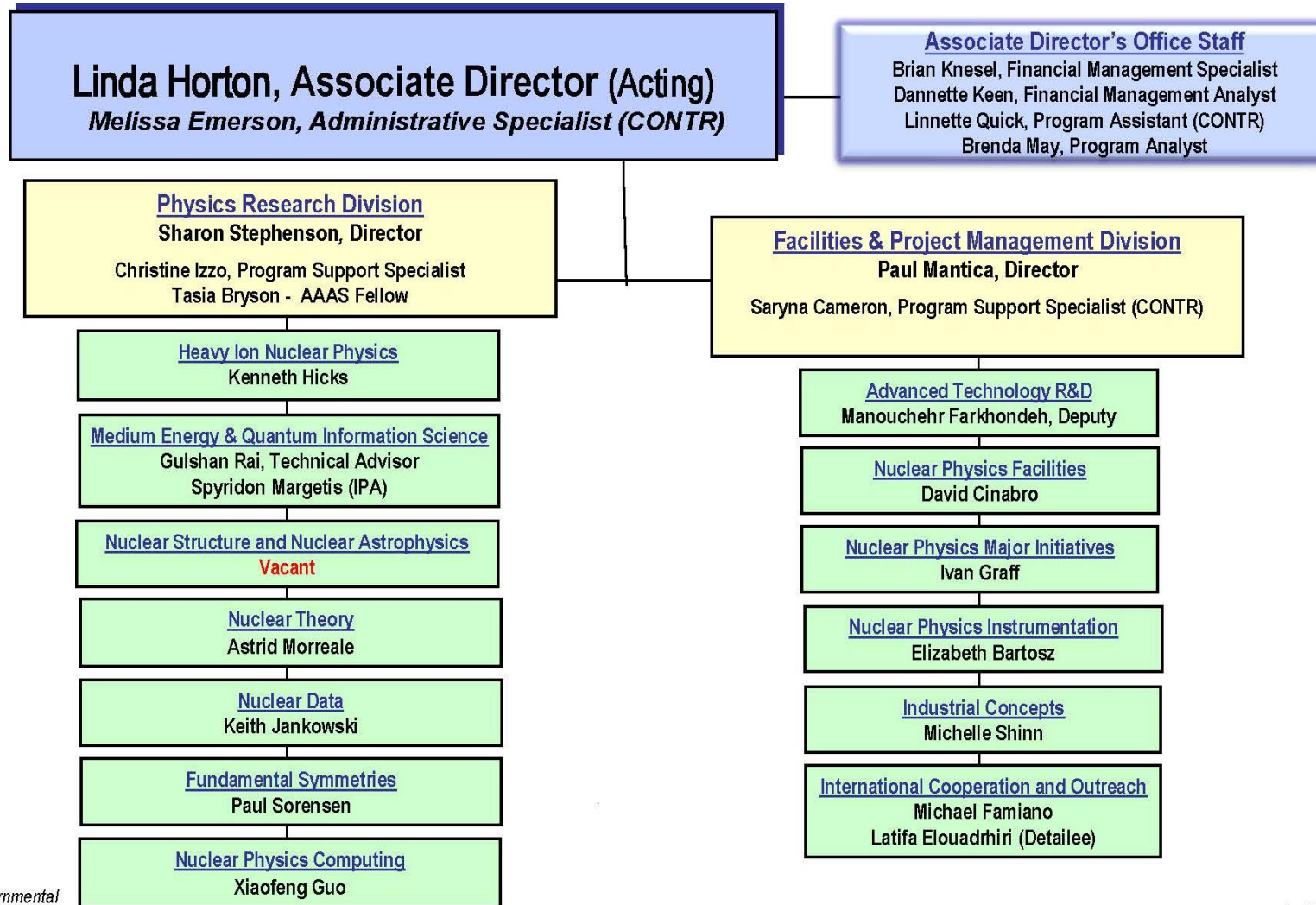


U.S. DEPARTMENT OF
ENERGY

Office of
Science

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DOE-SC Office of Nuclear Physics



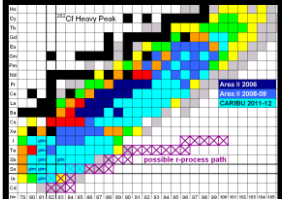
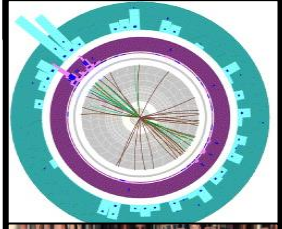
(IPA) –
Intergovernmental
Personnel Act

April 8, 2024

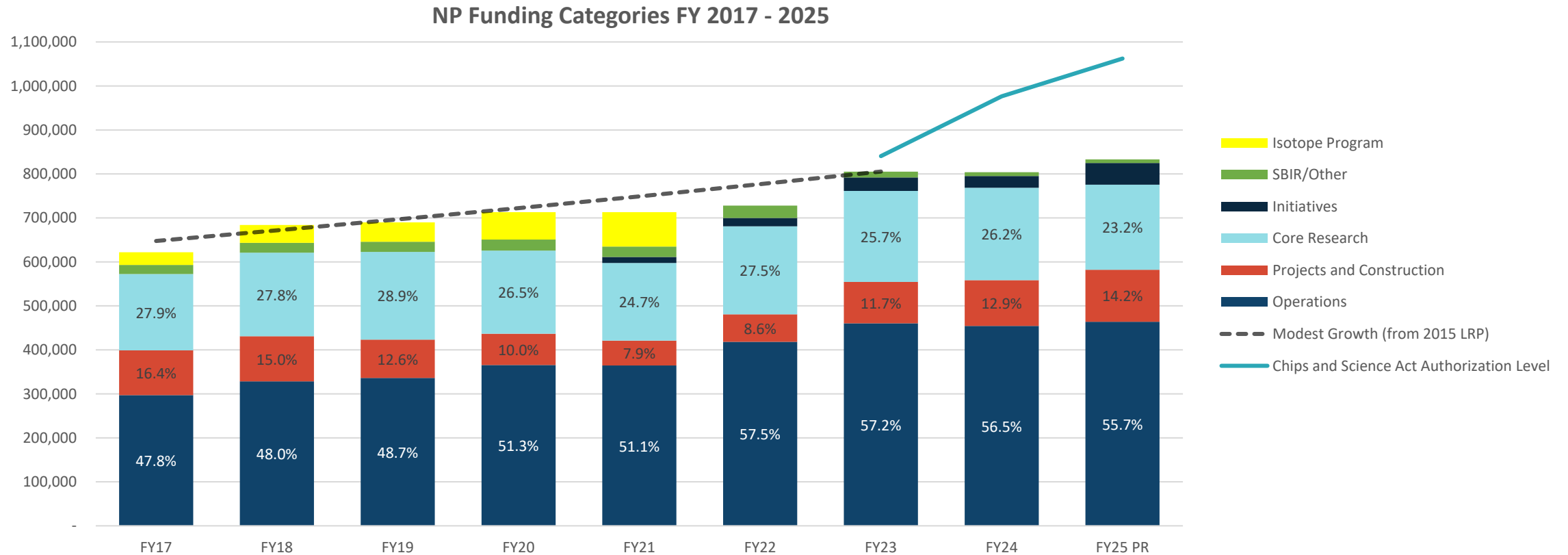
DOE Nuclear Physics Program

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



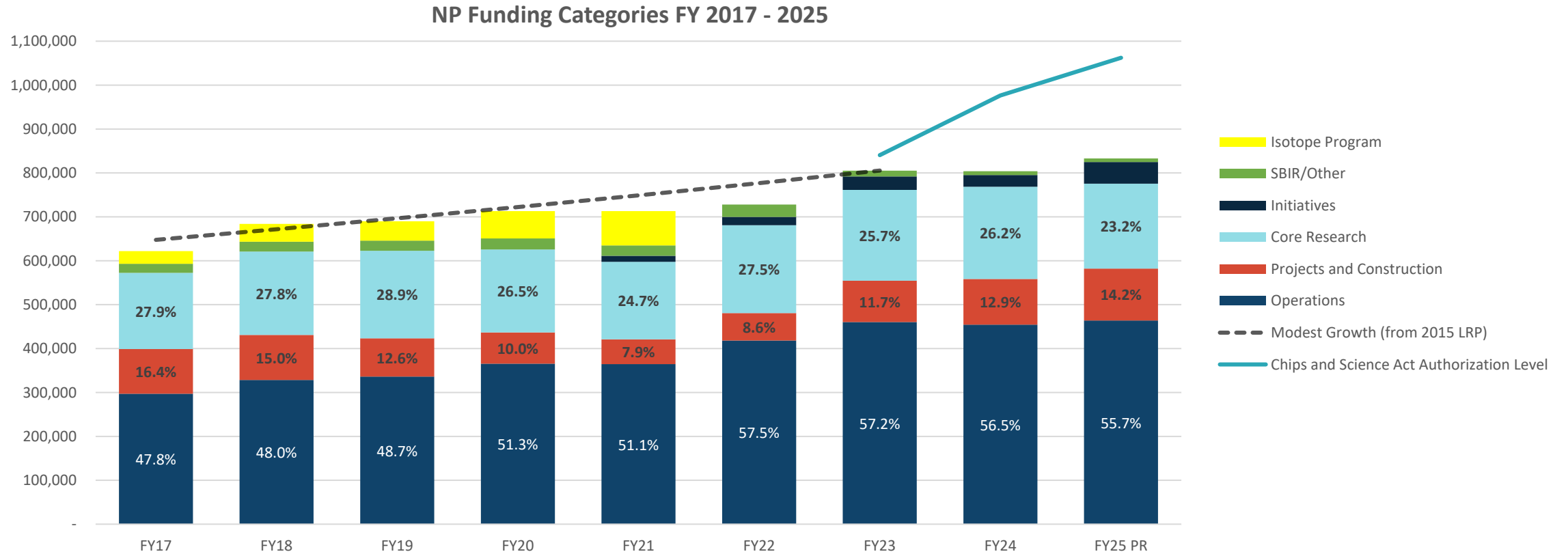
The Trend in DOE-NP Appropriations: FY 2024 appropriation (\$804M) is approximately flat with FY 2023



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



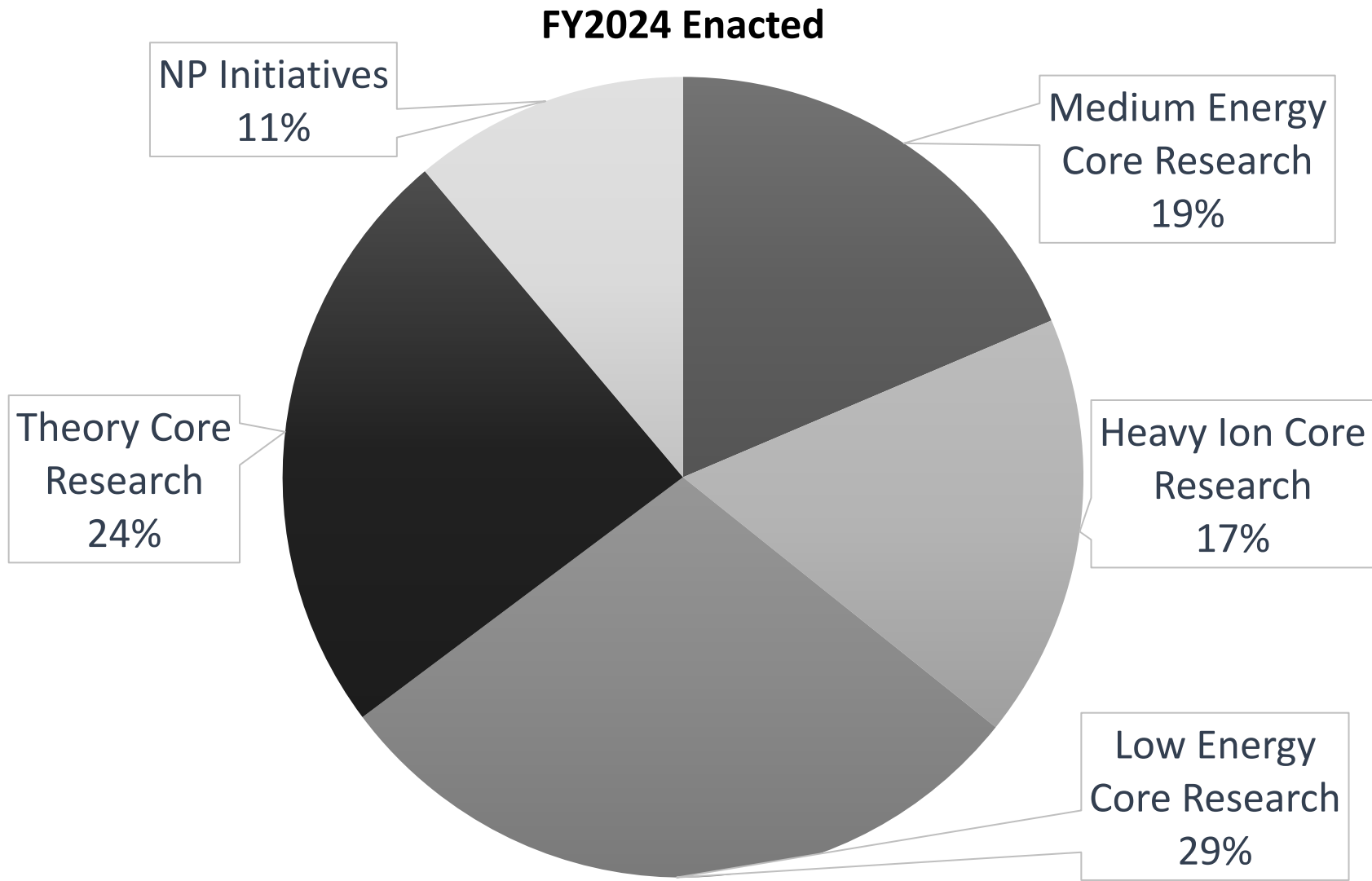
FY 2025 President's Budget Request supports user facility operations at >90% of the funding level required for full operations. Increase support for construction is focused on EIC. For research, increased initiative support (+\$23M) focuses on AI/ML, RENEW, and FAIR; Core research is down by ~\$17M.

FY 2024 NP-RD Appropriations Overview

- \$256M FY2024 Enacted

- NP Initiatives:

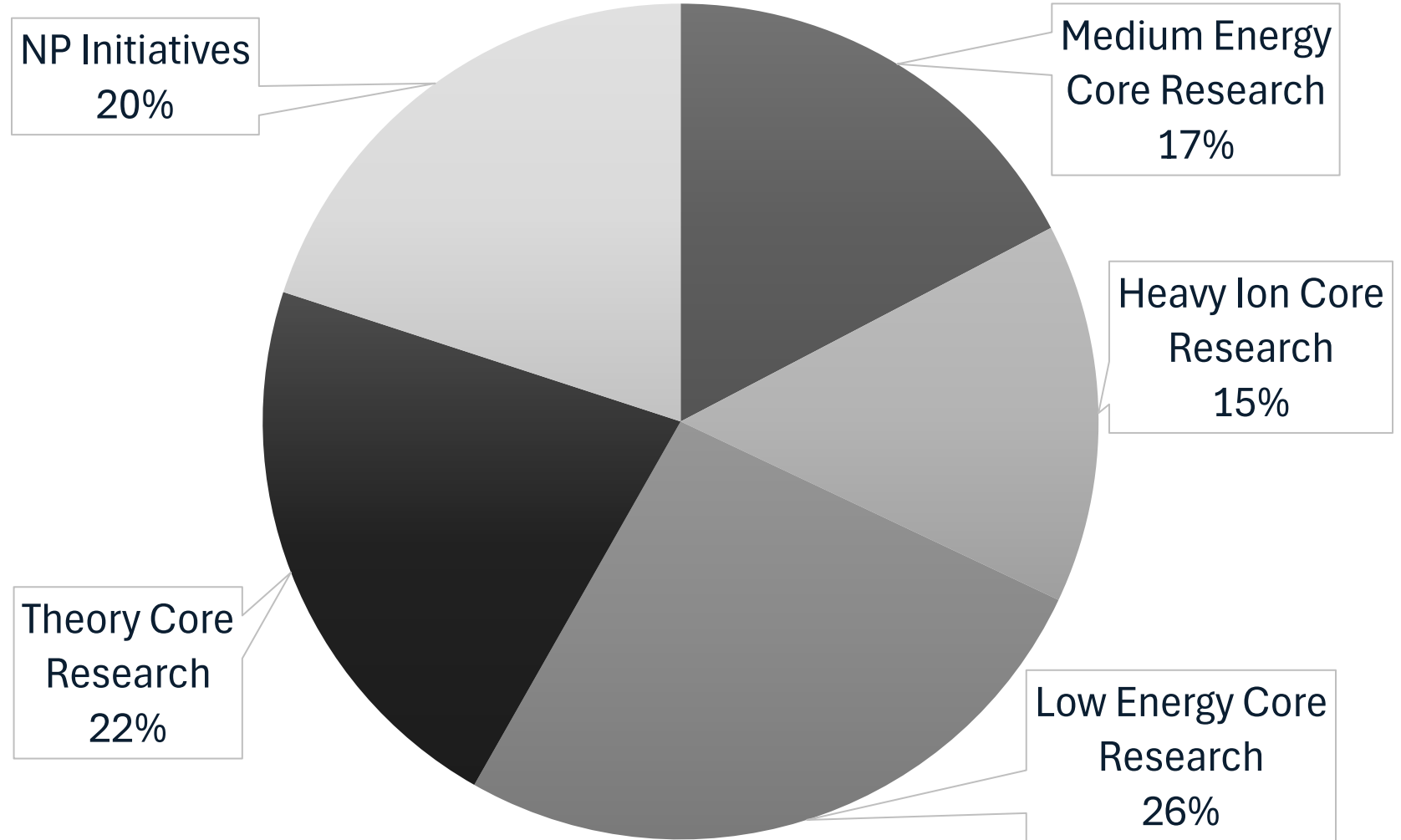
- *Microelectronics*
- *AI/ML*
- *QIS*
- *ACCELERATE*
- *RENEW*
- *FAIR*



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

Research Highlights

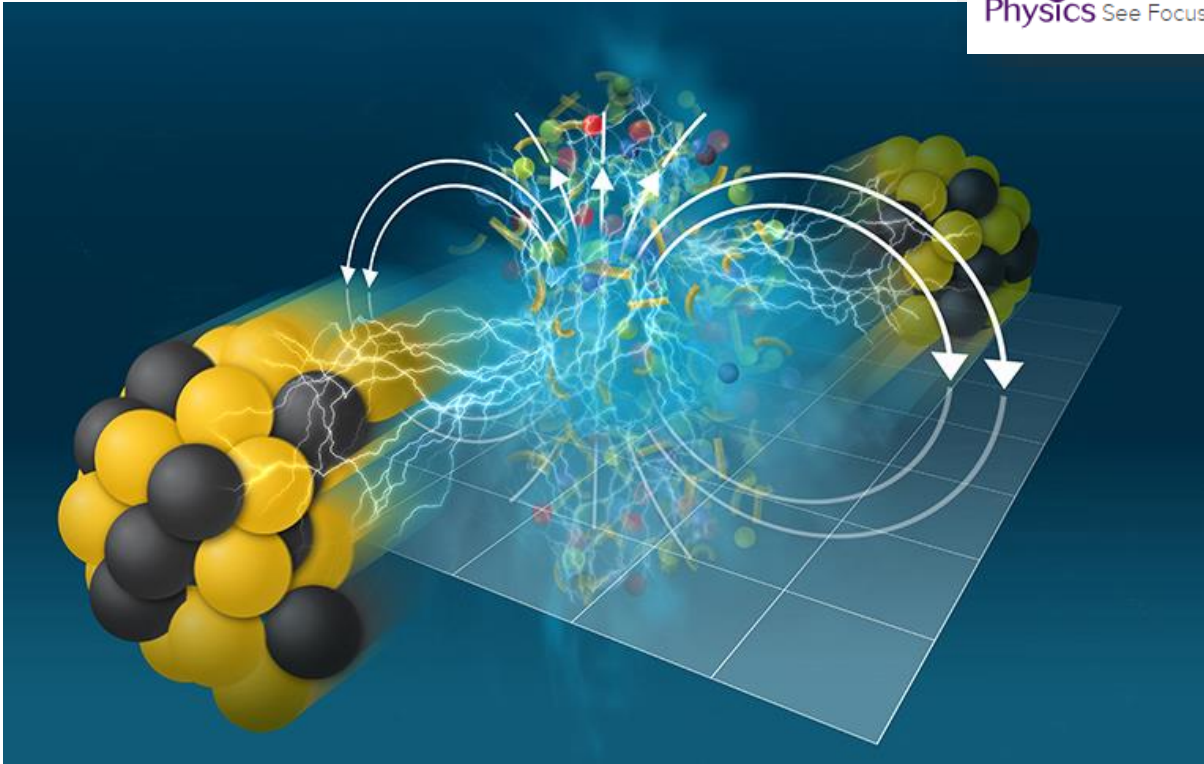
Featured in Physics

Open Access

Observation of the Electromagnetic Field Effect via Charge-Dependent Directed Flow in Heavy-Ion Collisions at the Relativistic Heavy Ion Collider

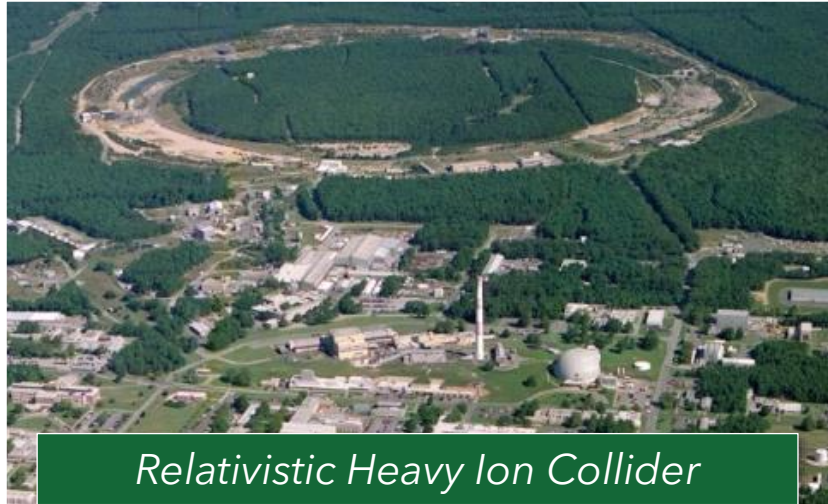
M. I. Abdulhamid *et al.* (STAR Collaboration)
Phys. Rev. X **14**, 011028 – Published 23 February 2024

PhysICS See Focus story: [Colossal Magnetic Field Detected in Nuclear Matter](#)



- ▲ Results in central collisions can be explained by transported quark effect
- ▲ Results in peripheral collisions reveal the contributions from Faraday induction and Coulomb effect for the first time in heavy-ion collisions

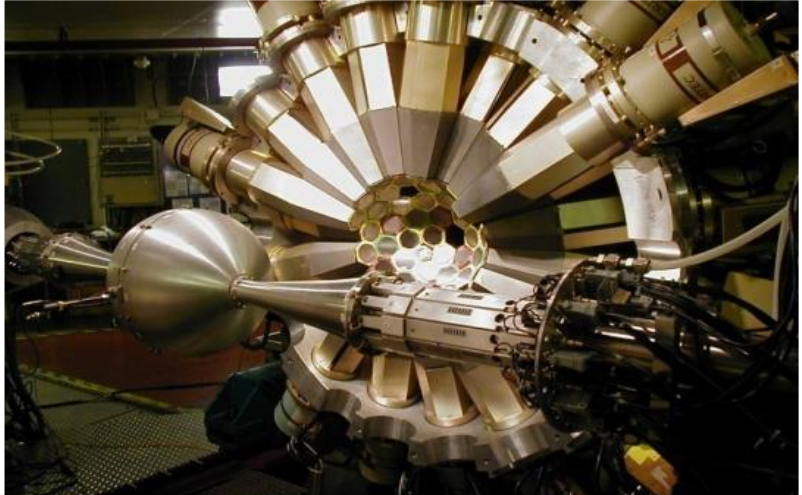
Four World-Leading National User Facilities Driving Advances



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)

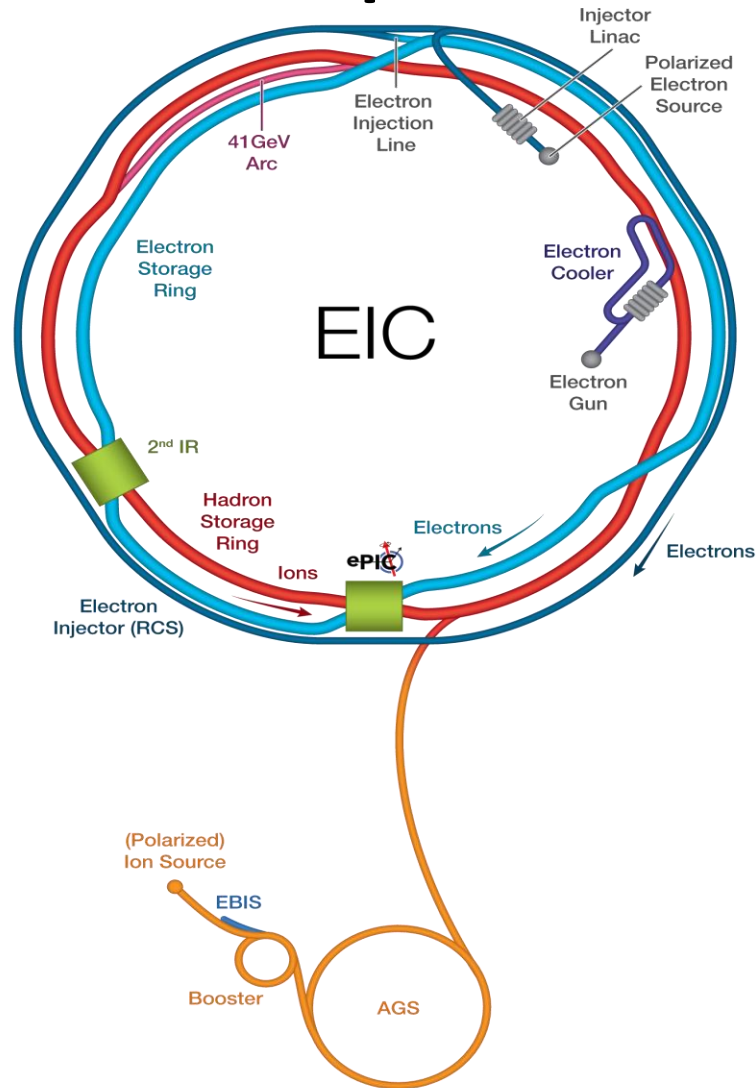
- ◆ RHIC is planning to run 25 weeks (including 6 additional weeks due to early end of Run 23) in FY 2024 focused on p+p data for sPHENIX and STAR
- ◆ CEBAF is planning to run 30 weeks in FY 2024 with the aim to complete experiments scheduled in Hall A; 3 additional weeks were added by replanning several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

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

Top Priority for New 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

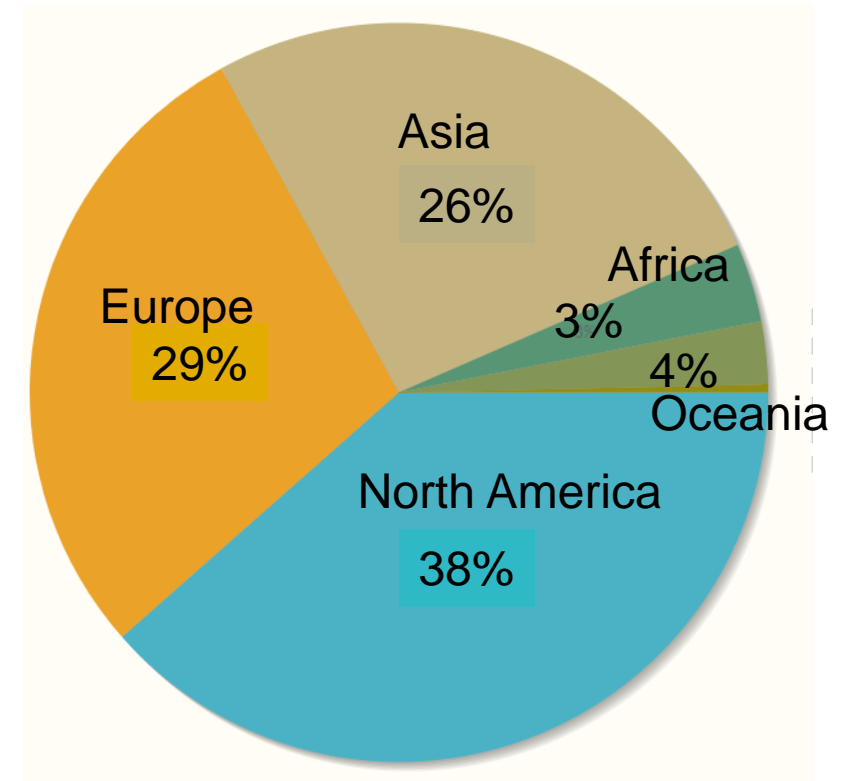
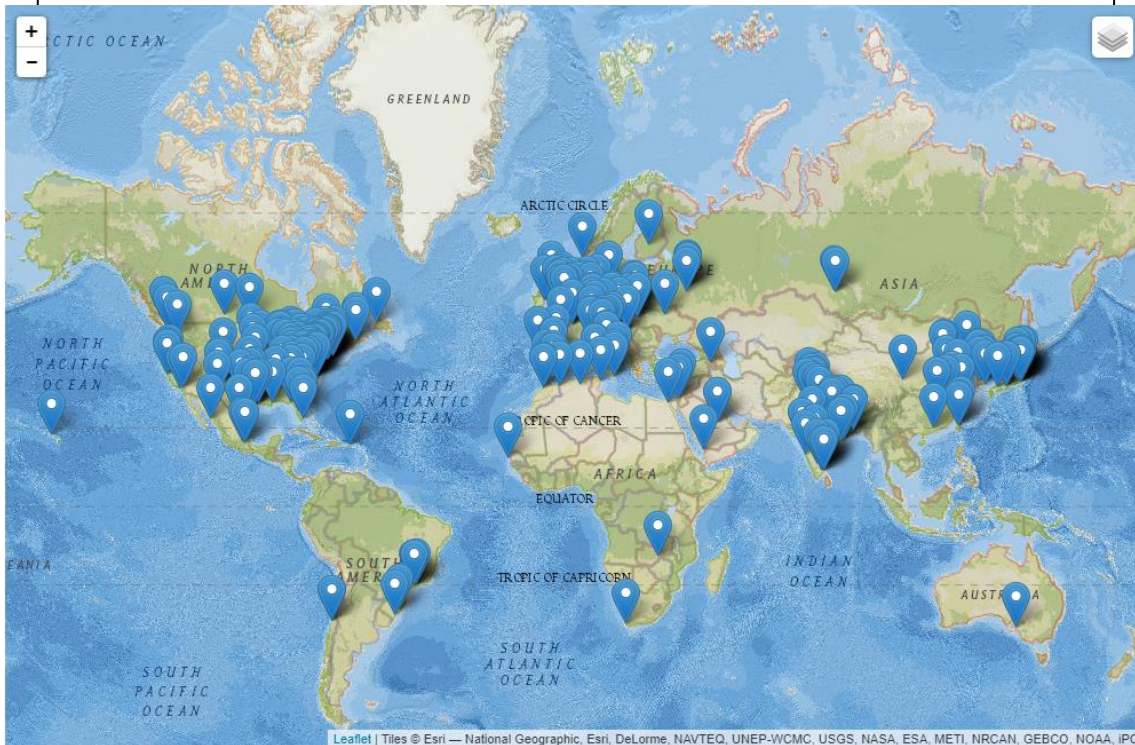
The Electron-Ion Collider is International at its Core

EIC Users Group Formed in 2016

EICUG.ORG

Status April 2024:

- ◆ Collaborators **1491**
- ◆ Institutions **291**
- ◆ Countries **40**



International Contributions to the Electron-Ion Collider

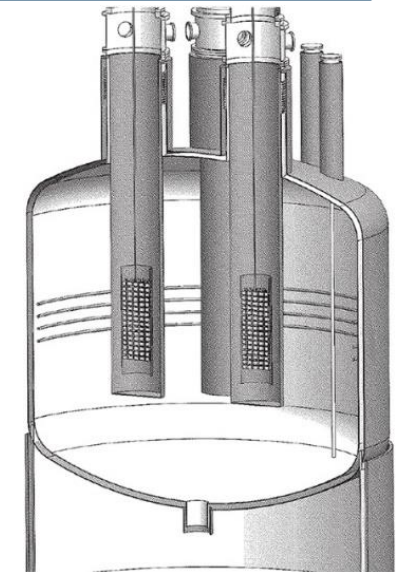
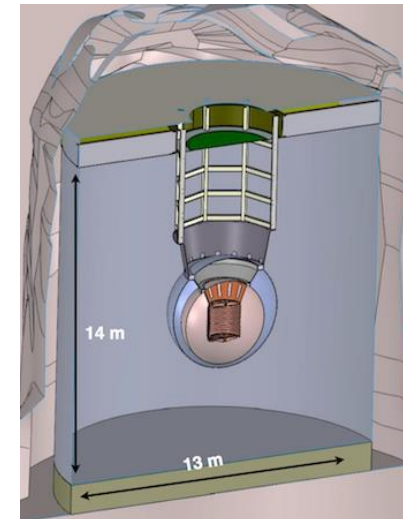
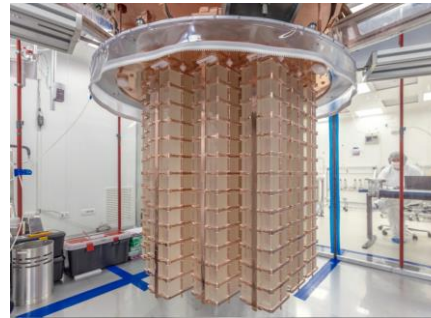
- ◆ The EIC Project is envisioning international contributions to the EIC detector of approximately \$100M, and contributions to the accelerator of approximately \$50M
 - 100% of these contributions have been notionally identified by international partners and interest continues to grow
- ◆ Two entities 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

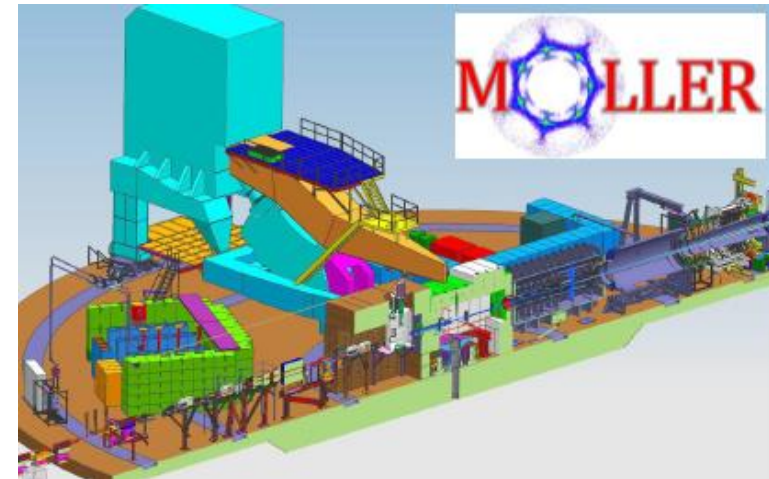
Status of other MIE Projects

Gamma Ray Energy Tracking Array (GRETA)



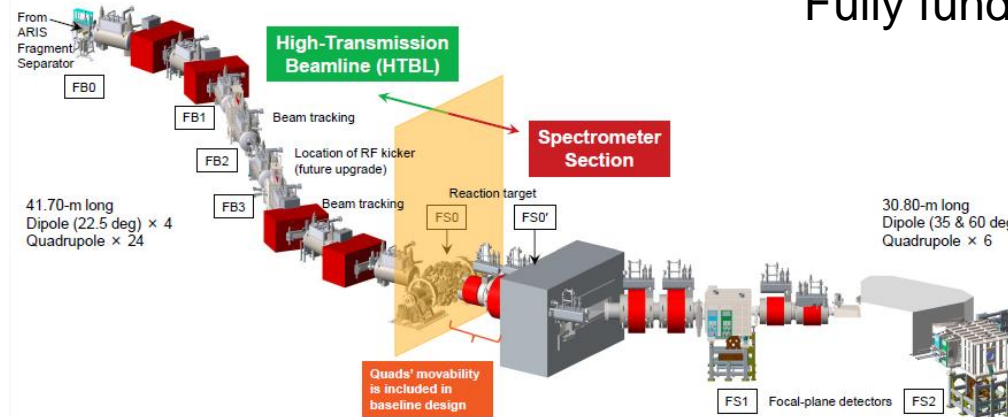
Fully funded; CD-4A forecast: Q3 FY 2025

Measurement of a Lepton-Lepton Electroweak Reaction (MOLLER)



Fully funded; CD-2/3 forecast: Q3 FY 2024

High Rigidity Spectrometer (HRS)



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

International Engagement Activities

◆ Recent Events

- DOE-CEA (France) Statement of Interest on EIC collaboration signed (November 13, 2023)
- Kickoff meeting of the CNRS-MSU International Research Lab (December 11-13, 2023)
- DOE-IN2P3 (France) Statement of Interest on EIC collaboration signed (February 1, 2024)
- NP-MEXT (Japan) science division meeting (February 28, 2024)
- **UKRI announces £58.8M award to support EIC construction (March 27, 2024)**
- NP-CNRS (France) program meeting (April 8, 2024)
- Meeting with Minister of University and Research of the Italian Republic (April 9, 2024)
- NP-INFN (Italy) bilateral meeting (April 11, 2024)
- EIC Advisory Board (April 19, 2024)
- CERN RRB (April 22-24, 2024)
- EIC RRB (May 6-7, 2024)



CNRS-MSU kickoff meeting attendees

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 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.

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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

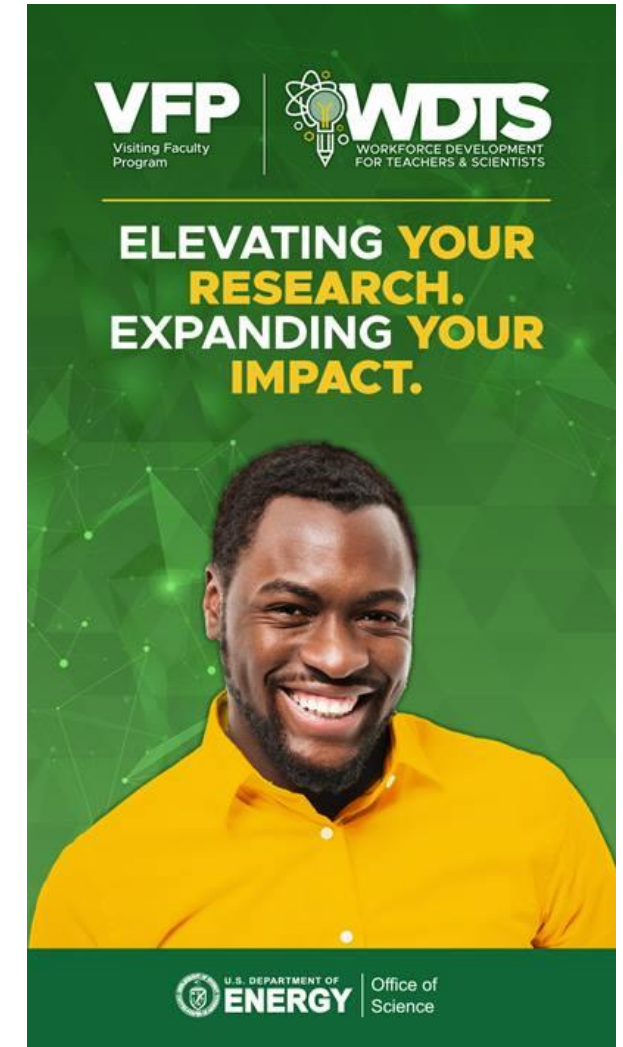
Supplemental awards to U.S. graduate students (US citizens or lawful permanent residents) to pursue part of their doctoral research at a DOE laboratory/facility in areas that address scientific challenges central to the Office of Science mission.

WDTS: Visiting Faculty Program

- Summer 10-week program. Option of inviting up to two students (one may be a graduate student).
- Returning VFP participants can apply for 10-week experiences in spring, fall terms; receive funding for teaching buyout.
- Two tracks:
 1. VFP Research Collaboration
 2. VFP Teaching Initiative Track (available for returning VFP participants)

- 113 VFPs awarded summer 2024, 6 NP scope
- 1 NP VFP in summer 2023, none in 2022

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



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