

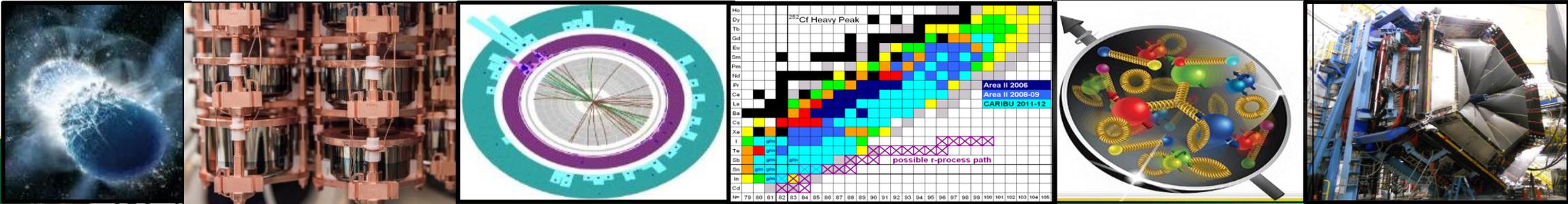
# DOE Nuclear Physics Research, Facilities, Priorities, and Challenges

NSAC Meeting

April 27, 2022

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for Nuclear Physics



# FY 2023 Request Highlights - NP

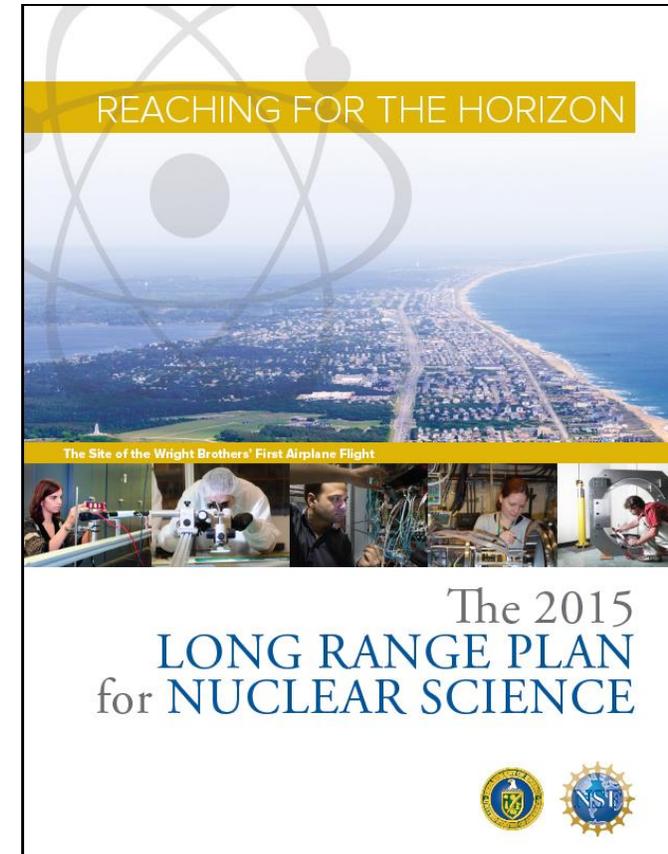
(B/A in thousands)

	FY 2021 Enacted	FY 2022 Enacted	FY 2023 Request	FY 2023 Request vs FY 2022 Enacted	FY 2023 Request vs FY 2021 Enacted
<b>Nuclear Physics</b>					
NP Operation and Maintenance	690,700	708,000	<b>719,196</b>	11,196 1.58%	28,496 4.13%
<b>Program Subtotal</b>	<b>690,700</b>	<b>708,000</b>	<b>719,196</b>	<b>11,196</b> <b>1.58%</b>	<b>28,496</b> <b>4.13%</b>
14-SC-50, Facility for Rare Isotope Beams (FRIB), MSU	5,300	...	...	...	-5,300 -100.00%
20-SC-51, U.S. Stable Isotope Production and Research Center (SIPRC)	12,000	...	...	...	-12,000 -100.00%
20-SC-52, Electron Ion Collider (EIC), BNL	5,000	20,000	<b>20,000</b>	...	15,000 300.00%
<b>Construction Subtotal</b>	<b>22,300</b>	<b>20,000</b>	<b>20,000</b>	...	<b>-2,300</b> <b>-10.31%</b>
<b>Total Nuclear Physics</b>	<b>713,000</b>	<b>728,000</b>	<b>739,196</b>	<b>11,196</b> <b>1.54%</b>	<b>26,196</b> <b>3.67%</b>

- NP’s goal is to understand why matter takes on the specific forms observed in nature and how that knowledge can benefit society in the areas of energy, climate, commerce, medicine, and national security.
- From probing quarks and gluons inside protons, to searching for the largest nuclei that can exist, such as Tennessine; from understanding the matter that existed millionths of a second after the Big Bang to events happening in the cosmos today, NP supported activities encompass discovery research from the smallest to the largest, and through time and the evolution of the universe as well.
- The unique knowledge and skill-set required for nuclear physics research is producing important collateral advances in quantum information science, artificial intelligence, and diversity, equity, and inclusion.

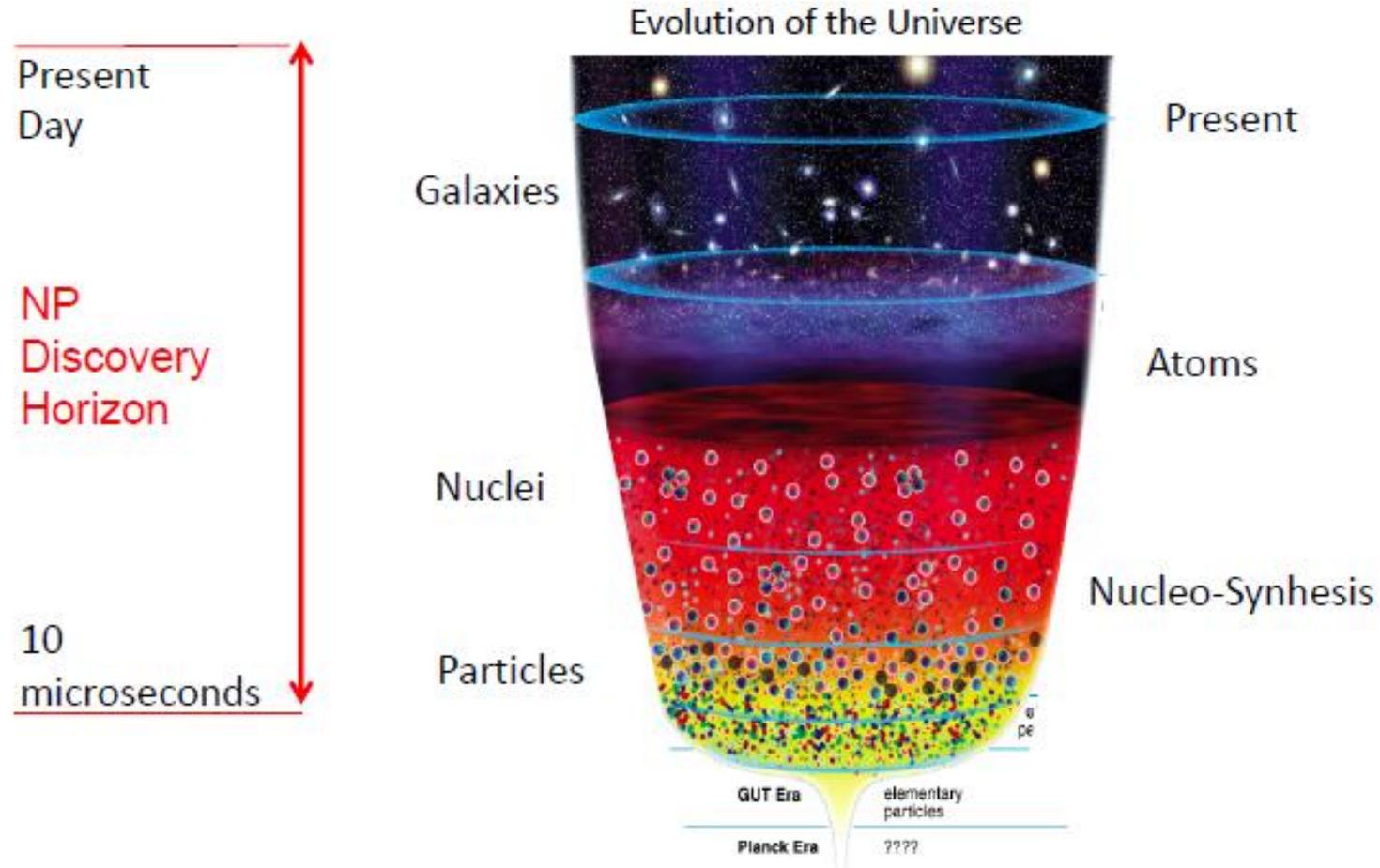
# The High-Level DOE NP Work Plan

1. Operate and get science out from RHIC, JLAB, ATLAS and FRIB
2. Make progress on a U.S.-led ton-scale neutrino-less double beta decay experiment.
3. Start construction of a high-energy high-luminosity polarized electron-ion collider (EIC)
4. Implement smaller scale instrumentation to take advantage of facility capabilities



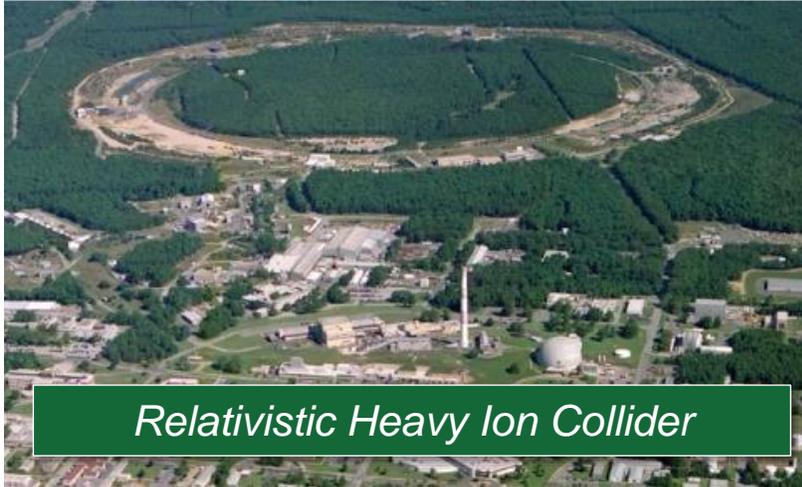
The work plan centers on NP's mission to understand all forms of nuclear matter to benefit energy, commerce, medicine, and national security.

# The Reach of DOE NP Science Research



The vast range of time ( $\mu\text{sec}$  to 13.8B years) and physical scales (quarks to galaxies) requires “microscopes” of varying resolving “power”

# A Major Part of NP Stewardship is Operating:



*Relativistic Heavy Ion Collider*



*Continuous Electron Beam Accelerator Facility*



*Argonne Tandem Linac System*



*Facility for Rare Isotope Beams*

“Microscopes” of Varying Resolving Power

# DOE NP is the Federal Steward of U.S. Nuclear Physics Research

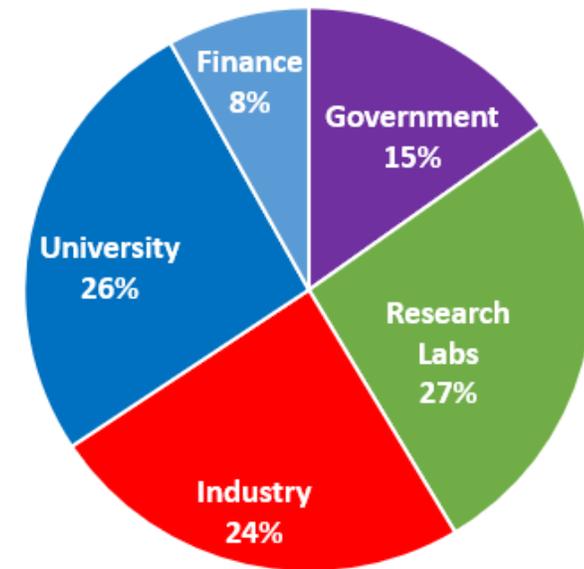
DOE NP supports ~ 95% of the nation's investment in basic research in nuclear physics in the U.S.

**It is responsible for Strategic Planning, Funding, and Implementation**

Where NP PHDs go

## Goals and Deliverables:

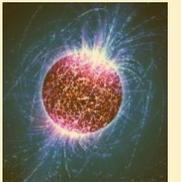
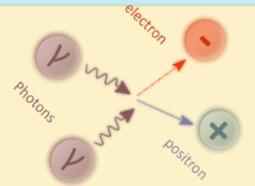
- Knowledge
- Leadership class facilities
- New technology
- A highly-trained, diverse workforce capable of supporting DOE & other missions



U.S. science, commerce, medicine, defense —all benefit, in part, from a stable level of sustained competence, capability, capacity, and leadership in nuclear physics; DOE NP is the U.S. steward responsible for reliably delivering that benefit.

# FY 2022 Enacted Highlights - NP

- ❑ FRIB and sPHENIX construction projects complete on cost and ahead of/on schedule
- ❑ The Electron-Ion Collider project completes the process to select a concept design for the Project Detector
- ❑ First known observation of the Breit-Wheeler two-photon process at RHIC
  - Suggests the possibility of direct production of  $e^+e^-$  pairs (matter) via lasers
- ❑ First-ever model independent sub—electron-volt limit set on the neutrino mass by KATRIN
- ❑ Discovery that heavy nuclei have a neutron skin (JLAB)
  - New constraints on neutron star radii and the nuclear equation of state
- ❑ Integration of AI technology in CEBAF accelerator operations to make them fault tolerant
- ❑ “Rodeo Algorithm” for quantum computing was developed offering a new approach, exponentially faster than other well-known algorithms. A high school student involved in the Rodeo Algorithm project was a top finalist in a national science talent competition.
- ❑ Successful cultivation in U.S. industry of new capability to hydroform cavities for superconducting radio frequency (SRF) cryomodules by ANL/Argonne Tandem Linac Accelerator System (ATLAS)



# FY 2022 Enacted Highlights - NP

- FRIB issued a call for proposals to its 1500 member user group.
- 82 proposals received from 130 institutions in 30 countries requesting 9,784 hours of beam time
- FRIB Program Advisory Committee Meeting held
- Ribbon cutting on May 2, 2022 to inaugurate the FRIB scientific program

## The Beginning of FRIB Data Taking



FRIB will be the world leader in Nuclear Structure & Nuclear Astrophysics research

# The Main Drivers Accounting for Requested FY 2022 Increases

The FY 2022 Enacted required large increases over FY2021 Enacted  
**\$728M vs \$635M (+93M )**

• CPP Plan at JLAB	\$6M
• Weeks at JLAB	\$19M
• EIC	\$20M
• Core Research	\$12.7M
• FRIB Ops	\$27M
• Nuclear Data	\$2.8M
• RENEW	\$3.0M
• Initiatives	<u>\$2.5M</u>
	\$93M

# NP FY 2022 Enacted and FY 2023 Request

	<b>FY22 Enacted</b>	<b>FY23 Request</b>
<b>Medium Energy</b>	<b>\$196.1M</b>	<b>\$193.7M</b>
CEBAF Ops	\$142.7M	\$143.4M
Research	\$53.4M	\$ 50.3M
<b>Heavy Ion</b>	<b>\$255.5M</b>	<b>\$245.0M</b>
RHIC Ops	\$183.9M	\$191.8M
Research	\$46.5M	\$ 43.2M
Projects	\$25.0M	\$10.0M
<b>Low Energy</b>	<b>\$199.1M</b>	<b>\$217.5M</b>
FRIB,ATLAS Ops	\$107.8M	\$125.5M
Research	\$73.9M	\$ 68.1M
Projects	\$17.4M	\$23.9M
<b>Theory</b>	<b>\$57.3M</b>	<b>\$63.0M</b>
Research	\$57.3M	\$63.0M
<b>Facility Construction</b>	<b>\$20.0M</b>	<b>\$20.0M</b>
EIC	\$20.0M	\$20.0M
<b>Total, NP</b>	<b>\$728.0M</b>	<b>\$739.2M</b>

Targeted increases are made in the FY 2023 Request compared to FY 2022 Enacted **\$739.2M vs \$728M (+11.2M)**

- |                         | <u>+Δ</u>   |
|-------------------------|-------------|
| • FRIB Ops              | \$15.8M     |
| • GRETA                 | \$6.5M      |
| • AI/ML                 | \$4M        |
| • RENEW                 | \$3M        |
| • FAIR Initiative       | \$2M        |
| • Accelerate Innovation | <u>\$4M</u> |

**\$35.3M**

Funds to support targeted increases above the overall NP increase come from the NP base.

# FY 2023 Request Highlights - NP

- ▶ FRIB begins its first full year of science research studying atomic number 28 nuclei near the limit for nuclear existence
- ▶ NP User Facilities (RHIC, CEBAF, ATLAS, and FRIB) all operate at or above 90% utilization
- ▶ The Electron-Ion Collider “memorializes” international in-kind contributions as part of finalizing preparations for CD-2 Review, *Approve Performance Baseline*. EIC A/E design is begun.
- ▶ sPHENIX begins science research at RHIC to determine the novel properties of the quark-gluon plasma
- ▶ LEGEND-200 begins initial search for new physics via the slowest rare decay ever attempted
- ▶ Funding for the Gamma Ray Energy Tracking Array (GRETA) MIE is in accordance with technically driven schedule
- ▶ NP investment in the AI/ML cross-cutting research and RENEW doubles
- ▶ NP participates in the new cross-cutting initiatives in Funding for Accelerated Inclusive Research (FAIR) and Accelerate Innovations in Emerging Technologies (Accelerate)



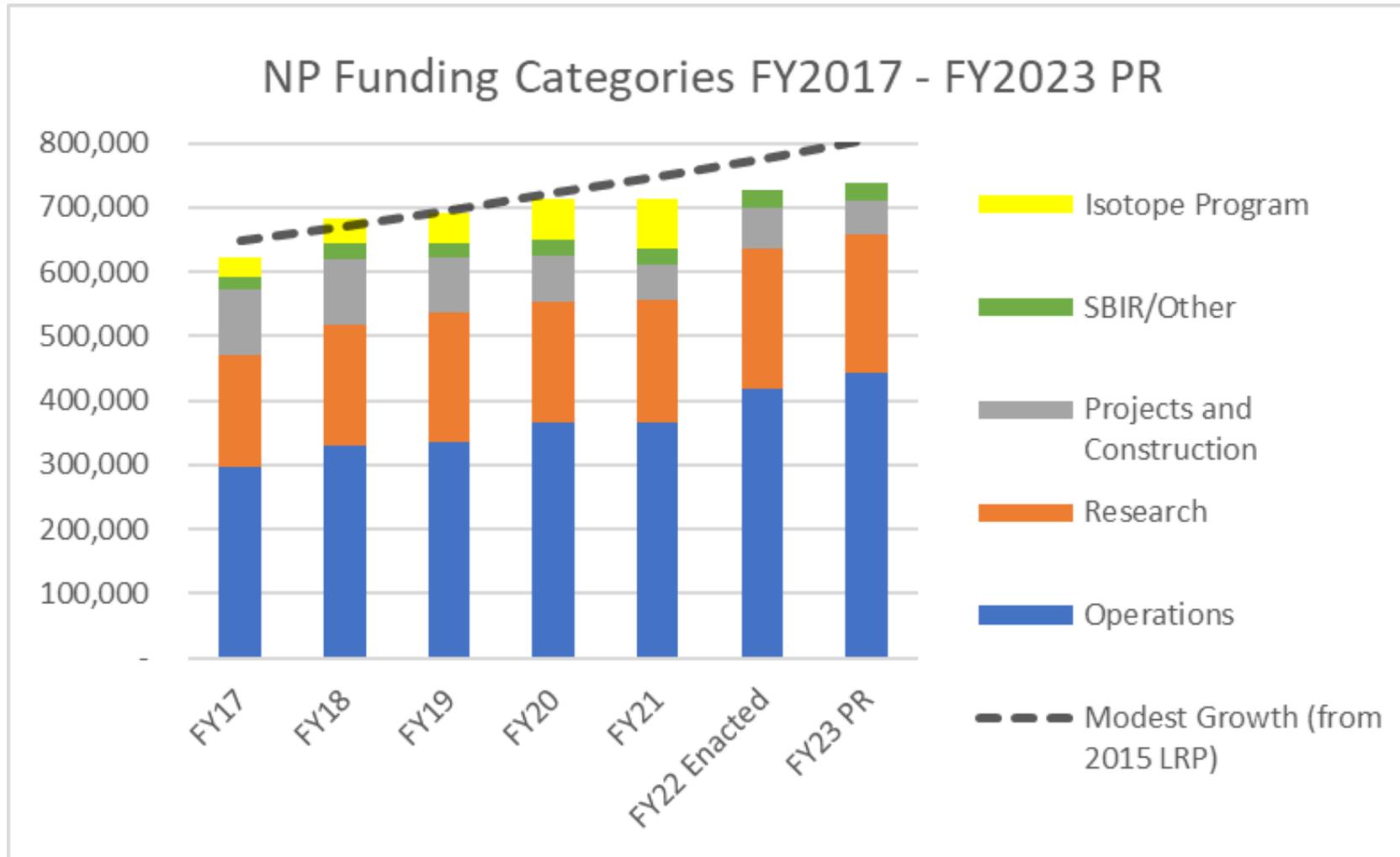
# NP Participation in SC Initiatives

SC/DOE Initiatives	FY21 Enacted	FY22 Enacted	FY23 PR
Quantum Information Sciences (QIS)	13,347	10,866	10,866
Artificial Intelligence and Machine Learning (AI)	4,000	4,000	8,000
Microelectronics	-	518	518
Strategic Accelerator Science and Technology Initiative	-	1,037	-
Reaching a New Energy Sciences Workforce (RENEW)	-	3,000	6,000
Funding for Accelerated, Inclusive Research (FAIR)	-	-	2,000
Accelerate Innovations in Emerging Technologies	-	-	4,000

Scientific Discovery Through Advanced Computing      \$      2,878      \$      3,543      \$      3,494

NP is also cultivating the possibility of a symbiosis with NIH to spark a significant advance in imaging useful for both DOE and NIH research

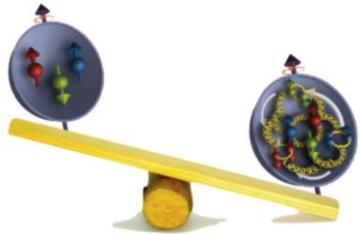
# The Trend of Appropriations Supporting the NP Work Plan



Recent Ops increases largely due to bringing FRIB online and making reliability upgrades at CEBAF

# Progress Continues on the Electron-Ion Collider

- Located at BNL and with TJNAF as a major partner. Estimated cost between \$1.7 and \$2.8 billion.
- Utilizes existing RHIC assets; adds electron storage ring, & electron cooling



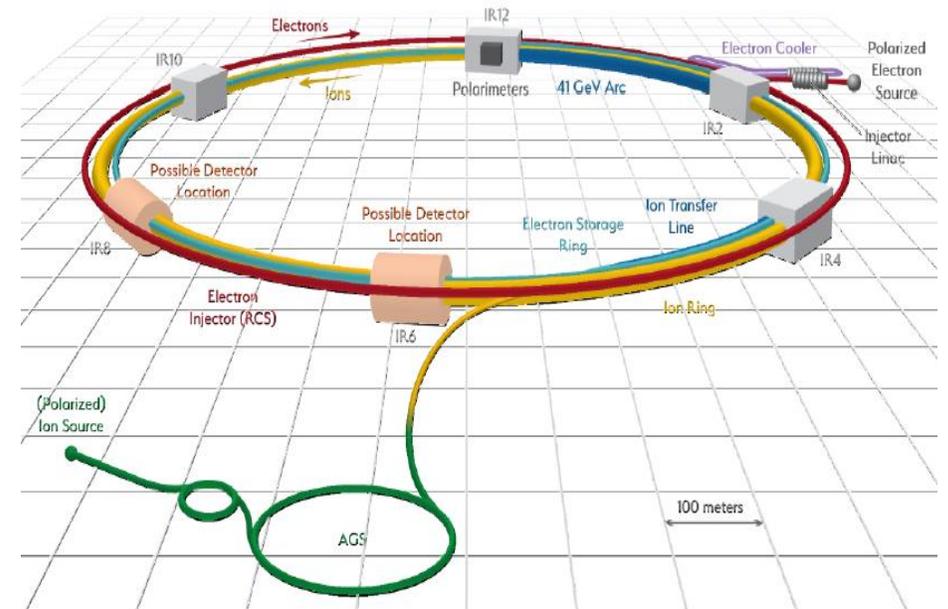
NAS: A US- based EIC will uniquely answer

- How does the mass of the nucleon arise?
- How does the spin of the nucleon arise?
- What are the emergent properties of dense systems of gluons?"

The international community is already highly engaged with 1110 collaborators, from 32 countries, and 235 institutions actively working on EIC development

\$ ~90M anticipated detector in-kind (~30%)  
\$ ~50M anticipated accelerator in-kind (~5%)  
\$100M grant from New York State

CD-1 was attained in June 2021.



toward the next DOE gateway, CD-2.

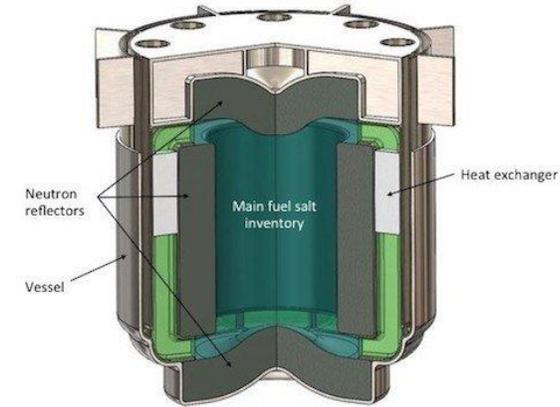
# NP Projects: Status and Operations Plan

Project	Location	Status	Cost	CPI	SPI	CD-4	Operation cost plan
<b>Construction Projects</b>							
Facility for Rare Isotope Beams (FRIB)	MSU	CD-3B	\$730M	1.00	1.00	6/2022	Included in NP budget formulation
Electron-Ion Collider (EIC)	BNL	CD-1	\$1.7B to \$2.8B			Q4 FY33	RHIC operations funds redirected to EIC project recovered for EIC operations
<b>Major Items of Equipment</b>							
Gamma Ray Energy Tracking Array (GRETA)	LBNL	CD-2/3	\$58.3M	0.98	0.94	4/2028	Mostly covered by host laboratory operations experimental support
Super Pioneering High Energy Nuclear Interaction Experiment (sPHENIX)* * Management oversight delegated to BNL	BNL	PD-3	\$27.0M	1.02	0.85	12/2022	Covered by RHIC operations experimental support
Measurement of Lepton-Lepton Electroweak Reactions (MOLLER)	TJNAF	CD-1	\$45.8M to \$56.6M			Q4 FY27	Covered by TJNAF operations experimental support
High Rigidity Spectrometer (HRS)	MSU	CD-1	\$85.0M to \$111.4M			Q2 FY29	Covered by FRIB operations experimental support
Ton Scale Neutrinoless Double Beta Decay (TS-NLDBD)	TBD	CD-0	\$215M to \$250M			TBD	TBD

Completed

# Contributions to Broader Impacts & Other Missions

- ▶ NP is providing new and updated nuclear data to existing “customers”
  - ▶ Working to identify impactful nuclear data needs and leverage resources
    - ▶ Ex: Advanced Reactors with DOE/NE, ARPA-E
- ▶ NP is reaching out to new nuclear data application customers
  - ▶ Electronics protection (NASA, Missile Defense Agency, Federal Aviation Administration)
  - ▶ Human safety (NASA [spaceflight], NIH [ion beam therapy])
  - ▶ Advanced reactors (ARPA-E, NASA)
- ▶ NP is exploring a mechanism for Rapid Response Nuclear Data
  - ▶ Many federal agencies have projects with nuclear data shortfalls
  - ▶ Project funding / scope does not cover nuclear data activities
  - ▶ USNDP is investigating a process where performers can submit requests for urgent, high impact nuclear data needs



NP Leads a Nuclear Data Interagency Working Group (NDIAWG) that published 4 FOAs

# FY 2022 Request Highlights - NP

## NP Traineeship Statistics

NP traineeship award recipients include:

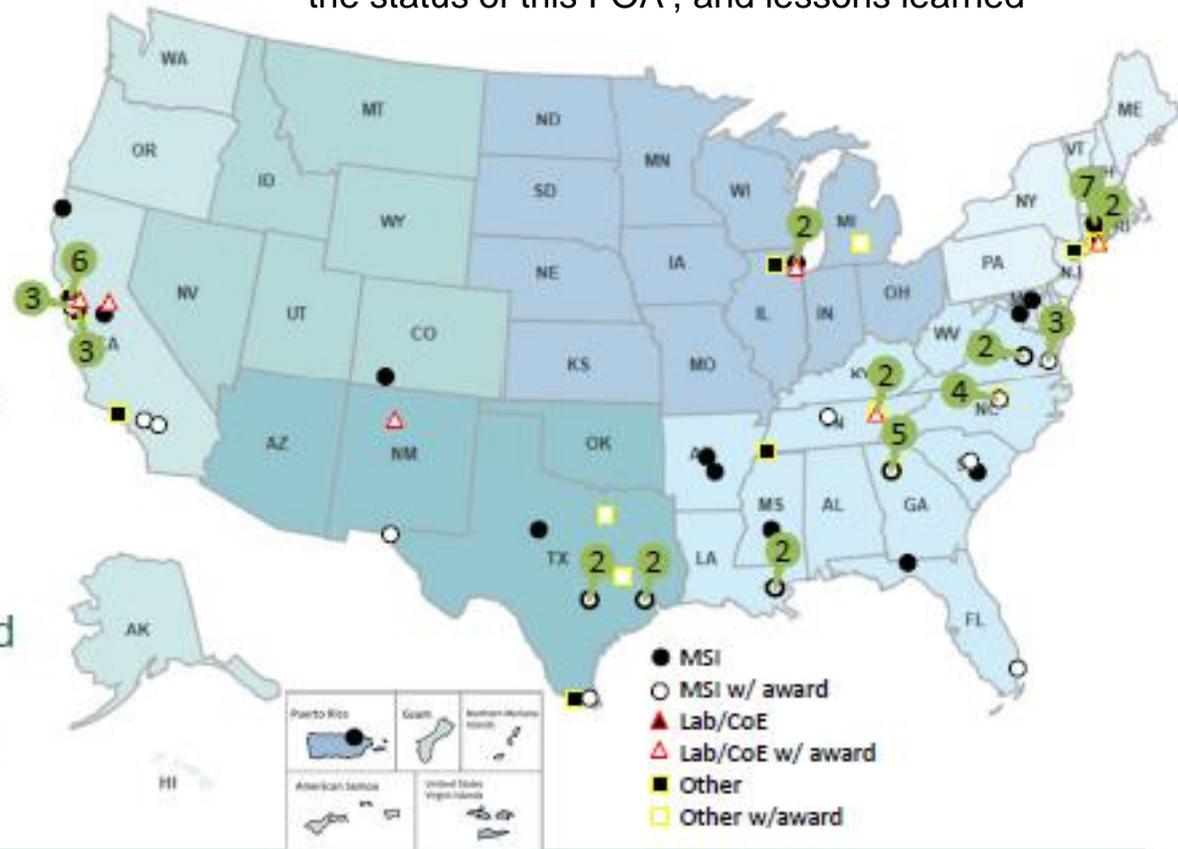
- 18 MSIs,
- 10 other colleges/universities,
- 5 DOE laboratories

MSI award recipient distinctions:

- 9 Hispanic Serving Institutions (HSIs),
- 8 HBCUs,
- 5 Asian American, Native American, and Pacific Islander Serving Institutions (AANAPISI),
- 1 Predominantly Black Institution (PBI)

All other institutions on the map are involved in the traineeship program as recruitment sites (38), Co-Is (9), members of INSIGHT (8), and/or hosts (7)

NP is preparing a Congressional Briefing on the status of this FOA , and lessons learned



# Other news

- Charge on Nuclear Data presented at the next NSAC Meeting, April 20, 2022 (Virtual)
- Plan for the charge for the next LRP to be delivered at the following NSAC meeting July 13, 2022 (In-Person).
- Ken Hicks is (almost) a Fed responsible for Heavy Ion Physics
- Astrid Morreale is now a Fed training with Paul Sorensen on Fundamental Symmetries and Nuclear Theory
- Paul Mantica is an IPA in charge of Facilities and Projects Division
- David Cinabro joins NP as a Fed to steward NP Facilities
- Michael Famiano joins NP as a Fed to help steward outreach and international collaboration
- Spiros Margetis is an IPA assisting Gulshan Rai with Medium Energy
- Dannette Keane is a new NP budget analyst with a primary focus on execution
- Melissa Emerson is the new administrative support person for the Associate Director
- Saryna Cameron is the new support person for the Facilities and Projects Division
- Kelsie Krafton is an AAAS Fellow stewarding DEI efforts in NP
- In general NP staff are “back in the office” with modified in-person schedules
- Based on lessons learned from the pandemic Fed travel will likely be reduced, in-person office presence will be reduced, remote work and telework will be more common. DOE supported travel is slowly opening back up. Masks are optional.



# A Long Tradition of Partnership and Stewardship

There has been a long tradition in Nuclear Science of effective partnership between the community and the agencies in charting compelling scientific visions for the future of nuclear science.

Key factors:

- 1) Informed scientific knowledge as the basis for recommendations and next steps
- 2) Mutual respect among scientific sub-disciplines
- 3) Commitment to the greater good of nuclear science as a discipline
- 4) Meticulously level playing field leading to respect for process and outcomes
- 5) Deep appreciation for the wisdom of Ben Franklin

Staying united we can accomplish great things together



Division will setback the entire field and is the last thing needed right now