U.S. DEPARTMENT OF ENERGY | Office of Science

A Few Perspectives from DOE's Office of Nuclear Physics

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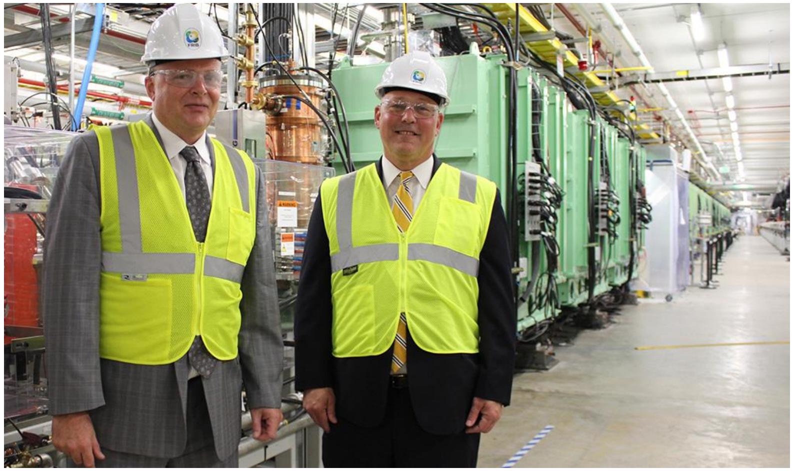
www.science.energy.gov

Biggest Recent News? Confirmation of Dr. Chris Fall

From *The Scientist*—
Fall is currently the principal deputy director of the Department of Energy's (DOE) Advanced Research Projects Agency-Energy (ARPA-E), which develops new research findings into commercial products. Before joining the DOE, he worked at the Office of Naval Research (ONR) for six years, where he oversaw studies of new technology for naval systems. Prior to that, he served for three years at the White House Office of Science and Technology Policy (OSTP) during President Obama's administration. In that role, Fall was the assistant director for Defense Programs and later, the acting lead for the National Security and International Affairs Division.
Fall was a faculty member in the bioengineering and anatomy and cell biology departments at the University of Illinois at Chicago before joining the Obama administration. During his career in research, he investigated energy production in neurons and the link between cellular signaling systems and cellular energy production. He holds a PhD in neuroscience from the University of Virginia.

Dr. Chris Fall has been confirmed as the new Office of Science Director



DOE's Office of Science: World Leading Science

To Meet the Nation's Challenges Today and into the 21st Century

The DOE Office of Science (SC) mission is the delivery of scientific discoveries and major scientific tools to transform our understanding of nature and advance the energy, economic, and national security of the United States.

- **Advancing the frontiers of science**
  - Providing largest Federal support in the physical sciences
  - Supporting **over 22,000** Ph.D.s, graduate students, undergraduates, engineers, and support staff at more than 300 universities and at all 17 DOE laboratories
- **Advancing DOE missions**
  - Supporting energy and environmental research including 36 Energy Frontier Research Centers and 4 Bioenergy Research Centers for the study of cellulosic biofuels
- **Serving the Nation's scientists**
  - Providing world-leading scientific user facilities to **over 32,000** users per year

Major Programmatic Responsibilities

Support of Fundamental Research

SC funds programs in physics, chemistry, materials science, biology, environmental science, applied mathematics, computer science and computational science, and is the Federal steward for several disciplines within these fields such as: high energy physics and nuclear physics; fusion sciences; high performance computing science and technology; and accelerator and detector science and technology. SC is also the largest Federal supporter of fundamental research relevant to future solutions for clean energy.

Support of 21st Century Tools for Science

SC supports the planning, design, construction, and operation of state-of-the-art scientific user facilities considered the most advanced tools of modern science. **Over 32,000** investigators perform research at these open-access facilities each year. Large facilities can have costs in excess of $1B and can be in design and construction for a decade. Most of our facilities are at DOE labs, but increasingly we engage in international cooperation due to the cost of some of the facilities.

Oversight of 10 DOE Laboratories

SC oversees the operation of 10 DOE national laboratories. It also conducts a formal laboratory strategic planning process annually with its labs to understand future directions, immediate and long-range challenges, and resource needs. As part of it's oversight of the laboratories, SC conducts an annual evaluation of the scientific, technological, managerial, and operational performance of the Management & Operating (M&O) contractors of its labs. In addition, SC funds mission-ready infrastructure and investments that foster safe and environmentally responsible operations at the labs.

R&D coordination and integration

SC coordinates its activities with the DOE technology offices, the National Nuclear Security Administration, and other federal agencies. This occurs through multi-program teams led by the DOE Under Secretary for Science (S4), SC and DOE program manager-driven informal working groups, and interagency working groups. New areas have focused on advanced materials, exascale computing, cybersecurity, subsurface technology R&D, and quantum information science. On-going coordination occurs in areas such as biofuels, solar energy utilization, superconductivity for grid applications, and vehicle technologies.

The Office of Science Research Portfolio

Advanced Scientific Computing Research	• Delivering world leading computational and networking capabilities to extend the frontiers of science and technology
Basic Energy Sciences	• Understanding, predicting, and ultimately controlling matter and energy flow at the electronic, atomic, and molecular levels
Biological and Environmental Research	• Understanding complex biological, earth, and environmental systems
Fusion Energy Sciences	• Building the scientific foundations for a fusion energy source
High Energy Physics	• Understanding how the universe works at its most fundamental level
Nuclear Physics	• Discovering, exploring, and understanding all forms of nuclear matter

DOE Support for SC National Laboratories

BERKELEY LAB

- Founded 1931
- 202 acres, 96 buildings
- 3,302 FTEs, including: 486 post-docs, 411 students, and 232 joint faculty
- 2,241 visiting scientists
- 11,403 facility users

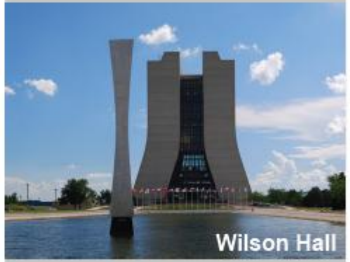
Pacific Northwest NATIONAL LABORATORY

- Founded 1965
- 781 acres, 71 buildings
- 4,238 FTEs, including: 256 post-docs, 745 students, and 64 joint faculty
- 302 visiting scientists
- 1,742 facility users

The Ames Laboratory

- Founded 1947 (1942)
- 10 acres, 13 buildings
- 307 FTEs, including: 46 post-docs, 174 students, and 43 joint faculty
- 321 visiting scientists

Fermilab



- Founded 1967
- 6,800 acres, 366 buildings
- 1,783 FTEs, including: 88 post-docs, 94 students, and 13 joint faculty
- 9 visiting scientists
- 3,472 facility users

Argonne NATIONAL LABORATORY

- Founded 1946 (1942)
- 1,517 acres, 154 buildings
- 3,225 FTEs, including: 273 post-docs, 569 students, and 274 joint faculty
- 1,107 visiting scientists
- 8,305 facility users

SLAC NATIONAL ACCELERATOR LABORATORY

- Founded 1962
- 426 acres, 149 buildings
- 1,531 FTEs, including: 152 post-docs, 299 students, and 36 joint faculty
- 19 visiting scientists
- 2,692 facility users

OAK RIDGE National Laboratory

- Founded 1943
- 4,421 acres, 271 buildings
- 4,957 FTEs, including: 320 post-docs, 633 students, and 214 joint faculty
- 1,888 visiting scientists
- 3,248 facility users

Jefferson Lab

- Founded 1962
- 169 acres, 69 buildings
- 1678 FTEs, including: 34 post-docs, 53 students, and 27 joint faculty
- 1,438 visiting scientists
- 1,597 facility users

PPPL PRINCETON PLASMA PHYSICS LABORATORY

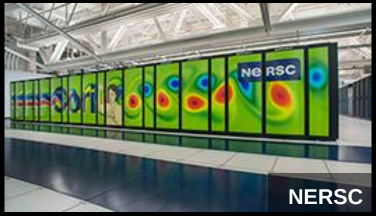
- Founded 1961 (1951)
- 91 acres, 30 buildings
- 495 FTEs, including: 21 post-docs, 48 students, and 6 joint faculty
- 50 visiting scientists
- 292 facility users

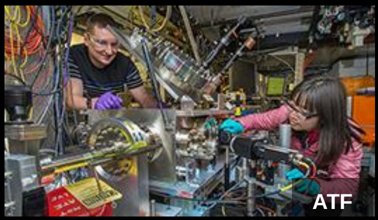
BROOKHAVEN NATIONAL LABORATORY

- Founded 1947
- 5,322 acres, 315 buildings
- 2,527 FTEs, including: 116 post-docs, 395 students, and 123 joint faculty
- 2,313 visiting scientists
- 2,923 facility users

FY 2020 President's Request User Facilities

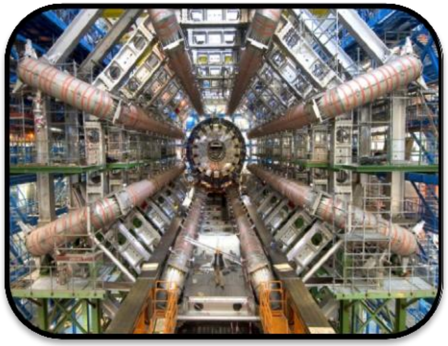
Number of User Facilities
27





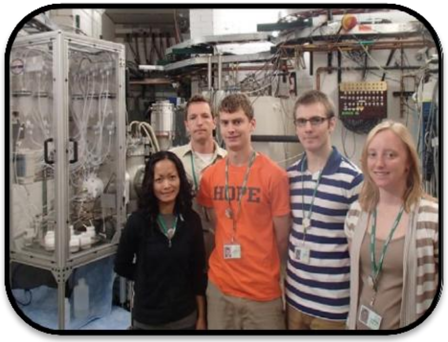
Office of Science at a Glance

FY 2020 Request: $5.55B



Largest Supporter of Physical Sciences in the U.S.

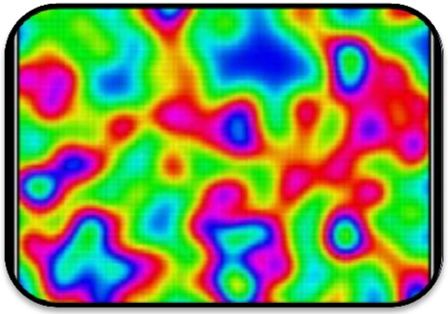
Funding at >300 Institutions, including 17 DOE Labs



Over 22,000 Researchers Supported

Over 32,000 Users of 27 SC Scientific Facilities

~40% of Research to Universities



Research: 40.6%, $2.25B

Facility Operations: 39.9%, $2.21B

Projects/Other: 19.5%, $1.09B

FY 2020 President's Budget Priorities

FY 2018 Enacted: $6.260B

FY 2019 Enacted: $6.585B

FY 2020 President's Request: $5.546B

Priorities:

- Continue operations of all the national laboratories
- Focus on the development of foundational Artificial Intelligence (AI) and Machine Learning (ML) capabilities
- Continue exascale computing research for delivery in FY 2021
- Expand quantum computing and quantum information science efforts
- Focus on cutting edge, early stage research and development
- Ensure a sustained pipeline for the science, technology, engineering, and mathematics (STEM) workforce

FY 2020 SC President's Budget Request

(Dollars in Thousands)

	FY 2018		FY 2019	FY 2020 Request		
	Enacted Approp.	Current Approp.	Enacted Approp.	President's Request	Request vs. FY 2019 Enacted	
Advanced Scientific Computing Research	810,000	788,224	935,500	920,888	-14,612	-1.6%
Basic Energy Sciences	2,090,000	2,028,719	2,166,000	1,858,285	-307,715	-14.2%
Biological and Environmental Research	673,000	648,600	705,000	494,434	-210,566	-29.9%
Fusion Energy Sciences	532,111	518,824	564,000	402,750	-161,250	-28.6%
High Energy Physics	908,000	883,573	980,000	768,038	-211,962	-21.6%
Nuclear Physics	684,000	664,694	690,000	624,854	-65,146	-9.4%
Workforce Development for Teachers and Scientists	19,500	19,500	22,500	19,500	-3,000	-13.3%
Science Laboratories Infrastructure	257,292	257,292	232,890	163,600	-69,290	-29.8%
Safeguards and Security	103,000	103,000	106,110	110,623	+4,513	+4.3%
Program Direction	183,000	183,000	183,000	183,000	...	...
SBIR/STTR (SC)	...	164,477	...	...	...	...
Subtotal, Office of Science	**6,259,903**	**6,259,903**	**6,585,000**	**5,545,972**	**-1,039,028**	**-15.8%**
SBIR/STTR (DOE)	...	116,972	...	...	...	...
Total, Office of Science	**6,259,903**	**6,376,875**	**6,585,000**	**5,545,972**	**-1,039,028**	**-15.8%**

Nuclear Physics FY2019 Budget Status

Nuclear Physics	FY 2018 Enacted	FY 2019 Enacted	FY 2019 Enacted vs FY 2018 Enacted
Operations and maintenance			
Medium Energy	174,953	184,190	+9,237
TJNAF Ops	*112,000*	*117,440*	*+5,440*
Heavy Ions	226,612	230,479	+3,867
RHIC Ops	*187,284*	*193,125*	*+5,841*
Low Energy	96,683	100,745	+4,062
ATLAS Ops	*21,000*	*21,630*	*+630*
FRIB Ops	*3,750*	*3,950*	
Nuclear Theory	47,852	55,327	+7,475
Isotope Program	40,700	44,259	+3,559
Undistributed	—	—	—
Total, Operations and maintenance	**586,800**	**615,000**	**+28,200**
Construction			
14-SC-50 Facility for Rare Isotope Beams	97,200	75,000	-22,200
Total, Construction	**97,200**	**75,000**	**-22,200**
Total, Nuclear Physics	**684,000**	**690,000**	**+6,000**

Enacted Appropriation: $690,000,000 for NP. Recommends $75,000,000 for FRIB and encourages early FRIB operations. Recommends $11,500,000 for SIPF MIE, $6,600,000 for GRETA MIE, and $5,660,000 for sPHENIX MIE. Recommends optimal operations for RHIC, CEBAF, ATLAS and BLIP.

President's FY2020 Request for NP is $624,854,000

FY2020 House Mark for NP is $735,000,000

Nuclear Physics

Discovering, exploring, and understanding all forms of nuclear matter

- Funding for research at national labs and universities is focused on the highest priority research in relativistic nuclear collisions, hadron physics, nuclear structure and nuclear astrophysics, and fundamental symmetries. NP continues its participation in planned coordinated SC **Quantum Information Science (QIS)** research and facility activities.

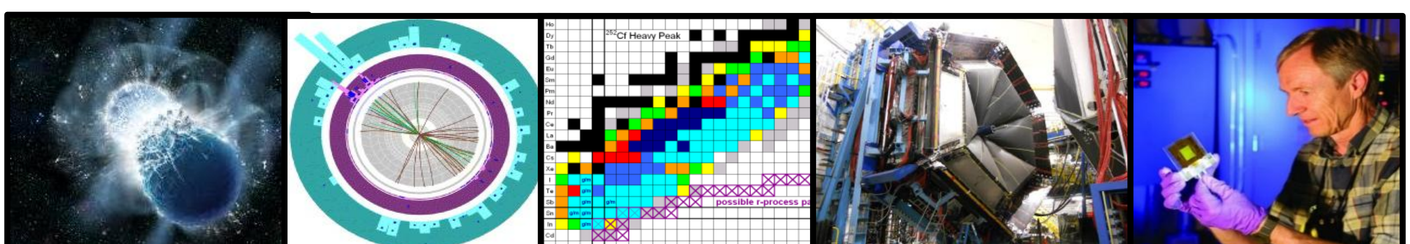
- **RHIC** operates at ~41% optimal to explore the properties of the quark gluon plasma first discovered there. The recently upgraded **12 GeV CEBAF** operates at ~24% optimal, promising new discoveries and an improved understanding of quark confinement. Operations at **ATLAS** are supported at ~31% optimal, providing high-quality beams of all the stable elements up to uranium, as well as selected beams of short-lived nuclei for nuclear structure and astrophysics experiments. **FRIB operations** begins to ramp up.

- Construction continues on the **Facility for Rare Isotope Beams. The Gamma-Ray Energy Tracking Array (GRETA)** MIE is continued to extend FRIB's reach in studying the nuclear landscape**.** The **sPHENIX MIE** continues within current RHIC funding levels for precision, high rate particle jet studies. The last year of funding is provided to the **Stable Isotope Production Facility (SIPF)** MIE to produce kilogram quantities of enriched stable isotopes.

- The **Moller MIE** is initiated for ultra-precise measurements with the upgraded CEBAF machine. The **Ton-Scale Neutrinoless Double Beta Decay MIE** is initiated to determine whether the neutrino is its own antiparticle. **The High Rigidity Spectrometer (HRS)** scientific equipment is supported to study beams of rare isotopes at maximum production rates for fragmentation.

- Conceptual design efforts and R&D (OPC) are supported for the planned **Electron Ion Collider (EIC)** whose critical importance to world-leadership in nuclear physics and accelerator science was recently affirmed by the National Academy of Sciences.

- Increased funding for the DOE Isotope Program supports robust mission readiness of facilities for isotope production and processing, university network operations, development of production capabilities of isotopes for QIS, and critical capital investments to increase availability of isotopes, including FRIB isotope harvesting. The **U.S. Stable Isotope Production and Research Center (SIPRC)** construction project is initiated to significantly increase production capabilities for stable isotopes and eliminate sole dependence on foreign supply.



The Nuclear Physics program supports basic research into the fundamental particles that compose nuclear matter, how they interact, and how they combine to form the different types of matter observed in the universe today.

Operations and Maintenance.—Within available funds, the recommendation provides $10,000,000 for Electron Ion Collider R&D.

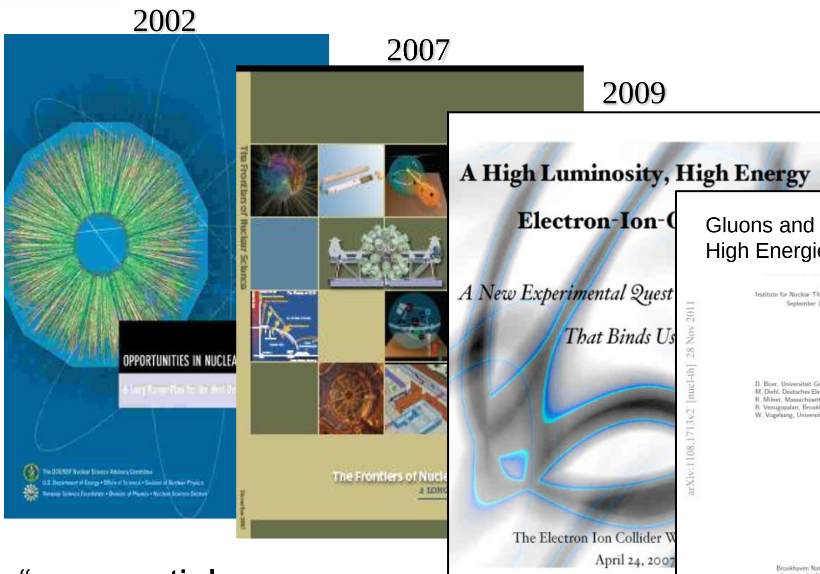
The Department is directed to give priority to optimizing operations within Medium Energy Nuclear Physics and at the Facility for Rare Isotope Beams.

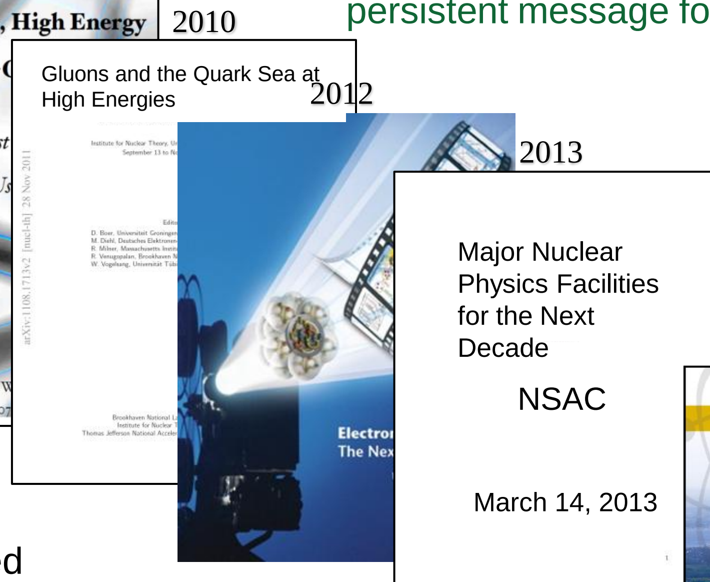
Within available funds, the recommendation provides $10,200,000 for the Gamma-Ray Energy Tracking Array, $9,520,000 for the Super Pioneering High Energy Nuclear Interaction Experiment, and not less than $2,500,000 for MOLLER.

https://docs.house.gov/meetings/AP/AP00/20190521/109534/HMKP-116-AP00-20190521-SD003.pdf

The Science Case for An Electron-Ion Collider

A strong community emphasis on the urgent need for a machine to illuminate the dynamical basis of hadron structure in terms of the fundamental quark and gluon fields has been a persistent message for almost two decades





"a high-energy high-luminosity polarized EIC [is] the highest priority for new facility construction following the completion of FRIB."

"…essential accelerator and detector R&D [for EIC] should be given very high priority in the short term."

"We recommend the allocation of resources …to lay the foundation for a polarized Electron-Ion Collider…"

"..a new dedicated facility will be essential for answering some of the most central questions."

"The quantitative study of matter in this new regime [where abundant gluons dominate] requires a new experimental facility: an Electron Ion Collider.."

Electron-Ion Collider..*absolutely central* to the nuclear science program of the next decade.

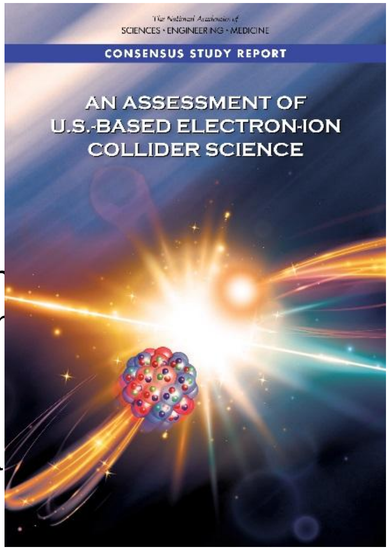
NAS Assessment of a U.S. Based Electron-Ion Collider

Finding 1: An EIC can uniquely address three profound questions about nucleons—neutrons and protons—and how they are assembled to form the nuclei of atoms:

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?



Finding 2: These three high-priority science questions can be answered by an EIC with polarized beams of electrons and ions, with sufficiently high luminosity and sufficient, ar variable, center-of-mass energy.

As a result of the comprehensive survey the committee made of existing and planned a both nuclear and particle physics around the world, it finds that

Finding 3: An EIC would be a unique facility in the world and would maintain U.S. leadership in nuclear physics.

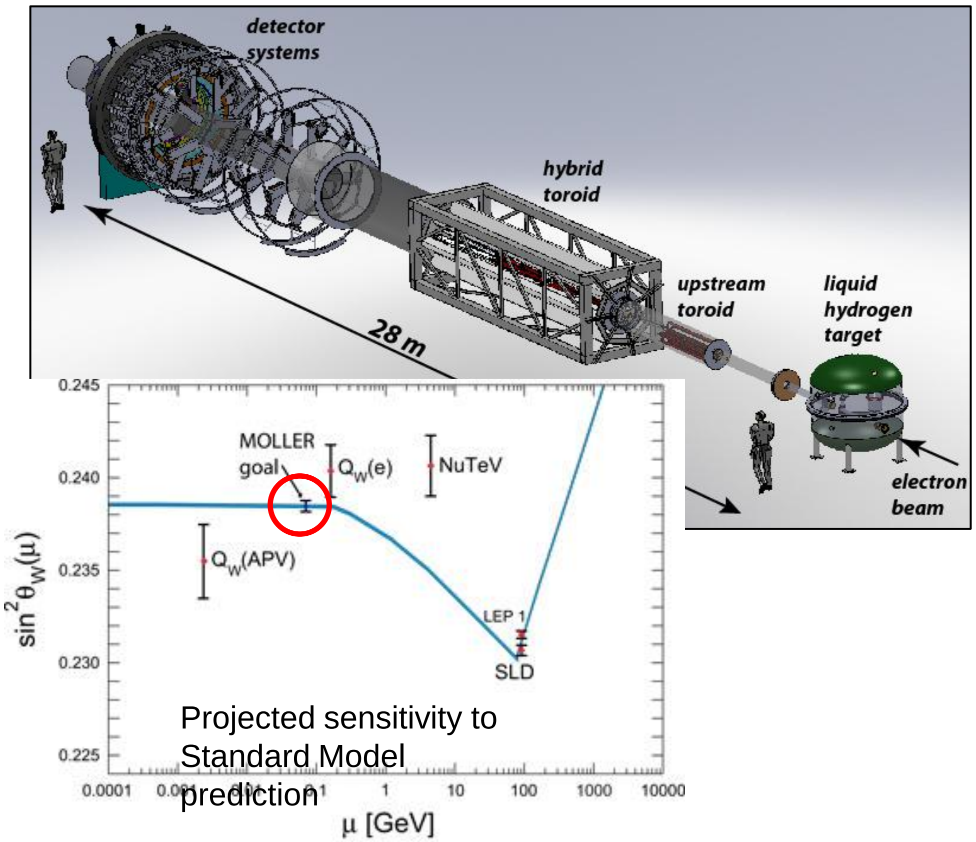
An EIC would be the only high-energy collider planned for construction in the United States. Its high design luminosity and highly polarized beams would push the frontiers of accelerator science and technology. For these reasons, the committee finds that

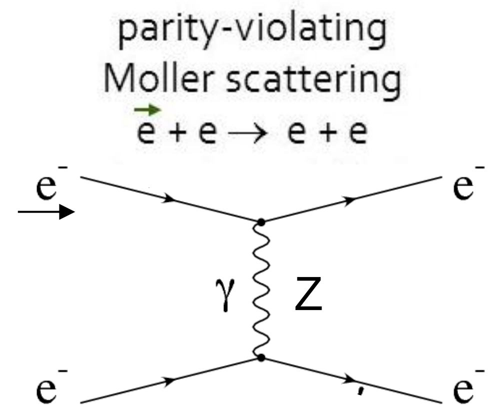
Finding 4: An EIC would maintain U.S. leadership in the accelerator science and technology of colliders and help to maintain scientific leadership more broadly.

Working towards CD0, OPC Funding of $1.5M Requested in FY2020

MOLLER: a “Must Do” Experiment To Point the Way to New Science

The scientific world rather desperately needs additional markers due to the consistency thus far of LHC data with Standard Model Predictions. Due to the technical challenge of constructing a next generation accelerator with very high accelerating gradients, those markers will have to come from “indirect” discovery experiments like MOLLER.





In MOLLER, polarized electrons are scattered of unpolarized electrons. The amount of parity violation due to interference of the two possible exchange mechanisms (γ or Z) is precisely predictable in QED. (No messy quarks or color charge, or QCD to worry about, only quantum electrodynamics). The theory is so “clean” that like the g-2 approach, If the level of parity violation is greater than expected, a new particle must be the source of the discrepancy.

Has CD0, TEC funding of $300k Included in the FY2020 Request

FY 2020 Priority Research Initiatives

Dollars in Thousands

Research Initiative	ASCR	BES	BER	FES	HEP	NP	Total
Machine Learning / Artificial Intelligence	36,000	10,000	3,000	7,000	15,000		**71,000**
Biosecurity			20,000				**20,000**
Quantum Information Science	51,161	52,503	12,000	7,520	38,308	7,000	**168,492**
Exascale Computing	463,735	26,000	10,000				**499,735**
Microelectronics		25,000					**25,000**
Isotope Development and Production for Research and Applications						47,500	**47,500**
U.S. Fusion Program Acceleration				4,000			**4,000**
Total	**550,896**	**113,503**	**45,000**	**18,520**	**53,308**	**54,500**	**835,727**

Machine Learning / Artificial Intelligence

Executive Office of the President (EOP) Priority

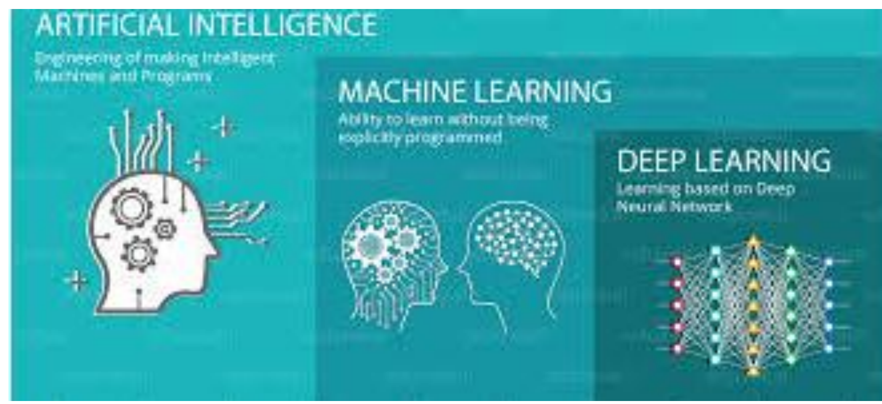
- Major U.S. Government initiative is in planning stage

Cuts across SC programs: ASCR, BES, BER, FES, and HEP, **many DOE programs:** OE, EE, FE, NE, NNSA, and **multiple U.S. Government Agencies, including NIH, DoD, and VA**

FY 2020 SC request - $71M, Funding is requested by NP

Nuclear Physics opportunities in Machine Learning for Data-Driven Science and Deep Learning. Artificial Neural Networks (ANNs) has played an important role in the analysis of nuclear physics data for decades. Recent application:

Predicting the properties of ^{6}Li nucleus like ground state energy and ground state point proton root-mean-square radius using a feed-forward ANNs. [Deep Learning: A Tool for Computational Nuclear Physics . arXiv:1803.03215]



Exascale Computing

EOP Priority

Cuts across SC research programs

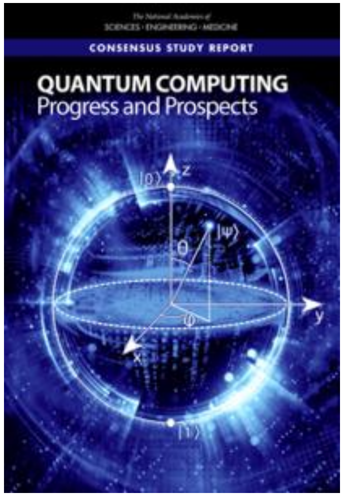
Exascale funded in FY 2018 ($413.5M) and FY 2019 ($513.7M)

FY 2020 SC request is $499.7M

Future of Exascale Computing Project (ECP) being studied by ASCAC

Quantum Information Science

US anticipates long-term, sustained support for developing a quantum ecosystem and economy, and for broad application of QIS and QC



EOP and Legislative Priority

- National Quantum Initiative Act Public Law 115-368

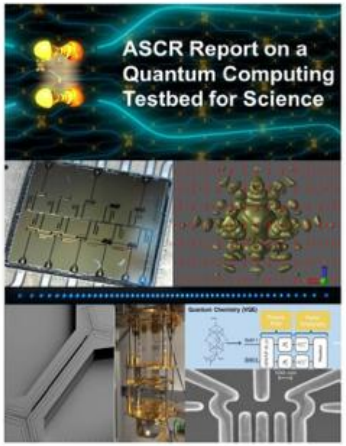
Cuts across all SC research programs, including DOE Isotope Program

Cuts across several other DOE programs

- OE and NNSA

QIS funded in FY 2018 ($62M) and FY 2019 ($123M)

FY 2020 proposal would focus on establishment of at least one DOE quantum center, budget request - $168.5M



The Committee supports the Office of Science's coordinated and focused research program in quantum information science and technology. This emerging field of science promises to yield revolutionary new approaches to computing, sensing, and communication. The recommendation includes funding for quantum information science research and establishment of National Quantum Information Science Research Centers.

Quantum Information Science Activities in Nuclear Physics

Joint Center for Quantum Information and Computer Science

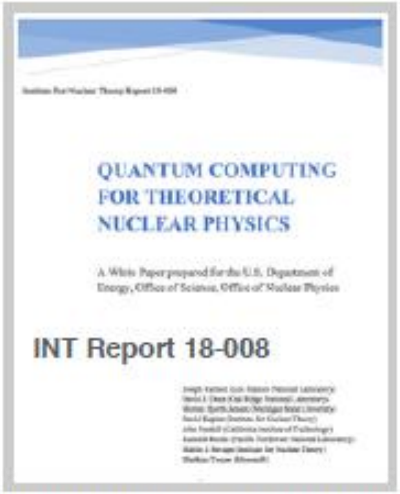
Institute for Nuclear Theory

NP∩QI

Computational Complexity and HEP
July-31 — August 2, 2017

Oak Ridge National Laboratory

Near-term Applications of Quantum Computing, December 6-7, 2017


QUANTUM COMPUTING FOR THEORETICAL NUCLEAR PHYSICS

A White Paper prepared for the U.S. Department of Energy, Office of Science, Office of Nuclear Physics

INT Report 18-008

Quantum Computing for Nuclear Physics
November 14-15, 2017

Intersections Between NP and QIS
Argonne National Laboratory
March 28-30, 2018

Center for Frontiers in Nuclear Science

Quantum Entanglement at Collider Energies

Stony Brook
September 10-12, 2018

Quantum Information Science and Quantum Computing for Nuclear Theory

FY 2018 NP QIS/QC Awards

Lead Insititution	PI	Title	Description
University of Washington	Martin Savage	Nuclear Physics Pre-Pilot Program in Quantum Computing	to support pre-pilot research activities that will begin to bring Quantum Computing (QC) and Quantum Information Science (QIS) expertise into the nuclear theory community, including starting to address scientific applications of importance for nuclear physics research. This pre-pilot proposal will organize the nuclear theory community at the national level in order to address Grand Challenge problems in nuclear physics through the use of QC and QIS.
MIT	Joseph Formaggio	Investigating Natural Radioactivity in Superconducting Qubits	to measure the impact of background radioactivity on qubit coherence times. MIT will be responsible for simulation of radiation transport models and development of calibration sources to be deployed in various qubit measurements. MIT will also coordinate this effort with Prof. William Oliver (MIT and Lincoln Labs). PNNL will be responsible for radioassay of materials using their calibrated measurement stations.
ANL	Ian Cloet	Quantum Simulators for Nuclear Physics: Theory	to support a postdoctoral fellow to work on the proposal for Quantum Simulations for Nuclear Physics. This pilot effort will begin to develop the expertise and knowledge that builds toward a QCD simulations on Quantum Computers and Analog Quantum Simulators.
ANL	Valentine Novosad	Superconducting Quantum Detectors for Nuclear Physics and QIS	to work on the proposal for Superconducting Quantum Detectors for Nuclear Physics and QIS.
LLNL	Stephan Frederich	Thorium 229mTh	to study of the feasibility of suppressing the internal conversion transition of 229mTh by implanting it in high band gap materials such as MgF_2

FY 2018 Awards Made Through Annual Solicitation

The FY2019 NP QIS FOA Has Been Released

U. S. Department of Energy Office of Science Nuclear Physics (NP)

Quantum Horizons: QIS Research and Innovation for Nuclear Science

A new initiative to identify, prioritize, and coordinate emerging opportunities in both fundamental research and applied challenges at the interface of Nuclear Physics and QIST. NP's Quantum Horizon's program emphasizes the science first approach and is guided by NP community research workshops: "Opportunities for Nuclear Physics & Quantum Information Science" and "Quantum Computing for Theoretical Nuclear Physics" and the "National Strategic Overview for Quantum Information Science", the Interagency Working Group on Quantum Information Science and the Exploration of the Quantum Landscape meetings of the Nuclear Science Advisory Committee

The response has been very enthusiastic
41 Applications submitted with a total request of ~ $38M

Plan is to Conduct Peer Review and Award $6.8M in FY2019

https://science.energy.gov/~/media/grants/pdf/foas/2019/SC_FOA_0002210.pdf

NSAC Assessment of the QIS Role of Nuclear Science is Ongoing

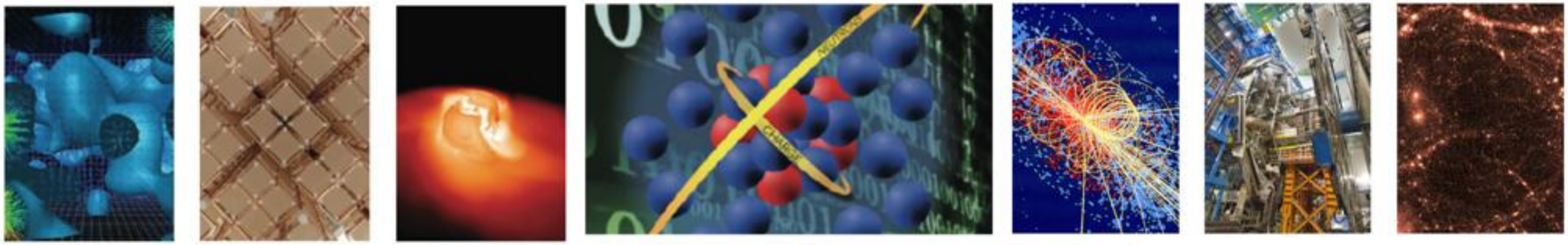
In some ways QIS/QC is not new to Nuclear Physics…

That said, the dramatic strengthening of this emphasis by the nation motivates a fresh look at the unique roles nuclear physics can and should play.

Decades of accumulated intellectual capital, extensive experience in interdisciplinary research, considerable technical infrastructure at labs and universities, and a long history of international leadership in collaborative research have positioned the DOE Office of Nuclear Physics and the NSF nuclear physics research programs to engage in QIS relevant research. However, QIS is newly emergent as a priority area for Research & Development (R&D) investment in nuclear science. Furthermore, private sector R&D investment in QIS, as well as investment by other Federal agencies, has been ongoing for some time. NSAC is therefore requested, in the context of Federal and private sector research efforts already underway, to articulate the unique role nuclear science research, aligned with the DOE and NSF nuclear physics programs, can and should play in Quantum Information Science. While unique, this role should nevertheless align broadly with the goals outlined in the national strategy for QIS[1].

[1] https://www.whitehouse.gov/wp-content/uploads/2018/09/National-Strategic-Overview-for-Quantum-Information-Science.pdf

NSAC Subcommittee Activities



MEETING #1

Bethesda, Maryland

Nuclear Physics Exploration of the Quantum Information Science and Quantum Computing Landscape

March 28-29, 2019

Doubletree by Hilton, 8120 Wisconsin Ave, Bethesda, Maryland 20814

MEETING #2

Seattle, Washington

Quantum Computing and Quantum Information Science: A Deep Dive

April 30 - May 1, 2019

University of Washington, HUB

Subcommittee gathered “high level” information from Meeting #1|
Meeting #2 deep dive including technology company panel

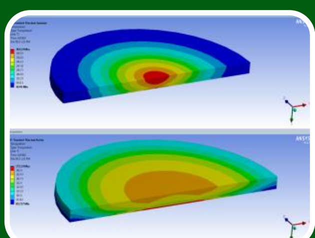
NSAC Report is due late summer

Community input will inform the FY 2020 QIS FOA

DOE Isotope Program Mission

Produce and/or distribute radioactive and stable isotopes that are in short supply; includes by-products, surplus materials and related isotope services

Maintain the infrastructure required to produce and supply priority isotope products and related service



Conduct R&D on new and improved isotope production and processing techniques which can make available priority isotopes for research and application. Develop workforce.

OMB moved Isotope Program from Office of Nuclear Energy to NP in FY 2009 Passback

National Isotopes Strategy

- **DOE Priority**
- **Possible Legislative Priority**
- Impacts other Agencies (DoD, NIH, HHS, ODNI, DHS, FBI, NIST, NSF, DOT, BLM, and NASA)
- Cuts across SC, IN, NE, and NNSA
- Provides research, technology, production capacity, and radiochemical processing for strategic stable & radioactive isotopes
- **FY 2020 SC request is $47.5M**

Stable Isotope Production Facility (SIPF) and SIPRC

- The upcoming FY 2020 Request will be the last year of support ($1.5M) for the SIPF MIE, which directly supports the DOE Isotope Program mission, upgrading domestic capability that has been lacking since 1998.
  - Renewed enrichment capability will benefit nuclear and physical sciences, industrial manufacturing, homeland security, and medicine.
  - Nurtures U.S. expertise in centrifuge technology and isotope enrichment that could be useful for a variety of peaceful-use activities.
  - Addresses U.S. demands for high priority isotopes needed for suite of activities: neutrinoless double beta decay, dark matter experiments, target material for Mo-99 production.
  - Help mitigate U.S. foreign dependence on stable isotope enrichment.

The next major step towards reliable U.S. supplies at scale is SIPRC at ORNL. TEC funding of $5M is requested in FY2020 as part of the National Isotope Strategy

SIPF responds to Nuclear Science Advisory Committee – Isotopes (NSACI):

- 2009 Recommendation: "Construct and operate an electromagnetic isotope separator facility for stable and long-lived radioactive isotopes."
- 2015 Long Range Plan: "We recommend completion and the establishment of effective, full intensity operations of the stable isotope separation capability at ORNL."

Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR)

Congress established the SBIR and STTR programs to support scientific excellence and technological innovation through the investment of Federal research funds in critical American priorities to build a strong national economy.

Federal agencies with large research and development (R&D) budgets set aside a small fraction of their funding for competitions among small businesses only. Small businesses that win awards in these R&D programs keep the rights to any technology developed and are encouraged to commercialize the technology.

	FY 2019	FY 2020	FY 2021
SBIR	3.2%	3.2%	3.2%
STTR	0.45%	0.45%	0.45%
Combined	**3.65%**	**3.65%**	**3.65%**

NP SBIR/STTR support all its research programs. FY2019 Key topics:

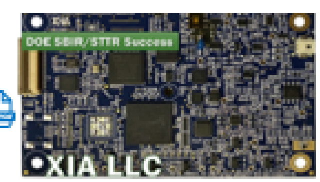
- Software and Data Management
- Electronics Design and Fabrication
- Accelerator Technology
- Instrumentation, Detection Systems and Techniques
- Isotope Science and Technology

Use SBIR/STTR funding to maintain leadership in technology areas where NP has unique needs. Every year subtopics are revised based on NP community and PM input

Recent Award Examples

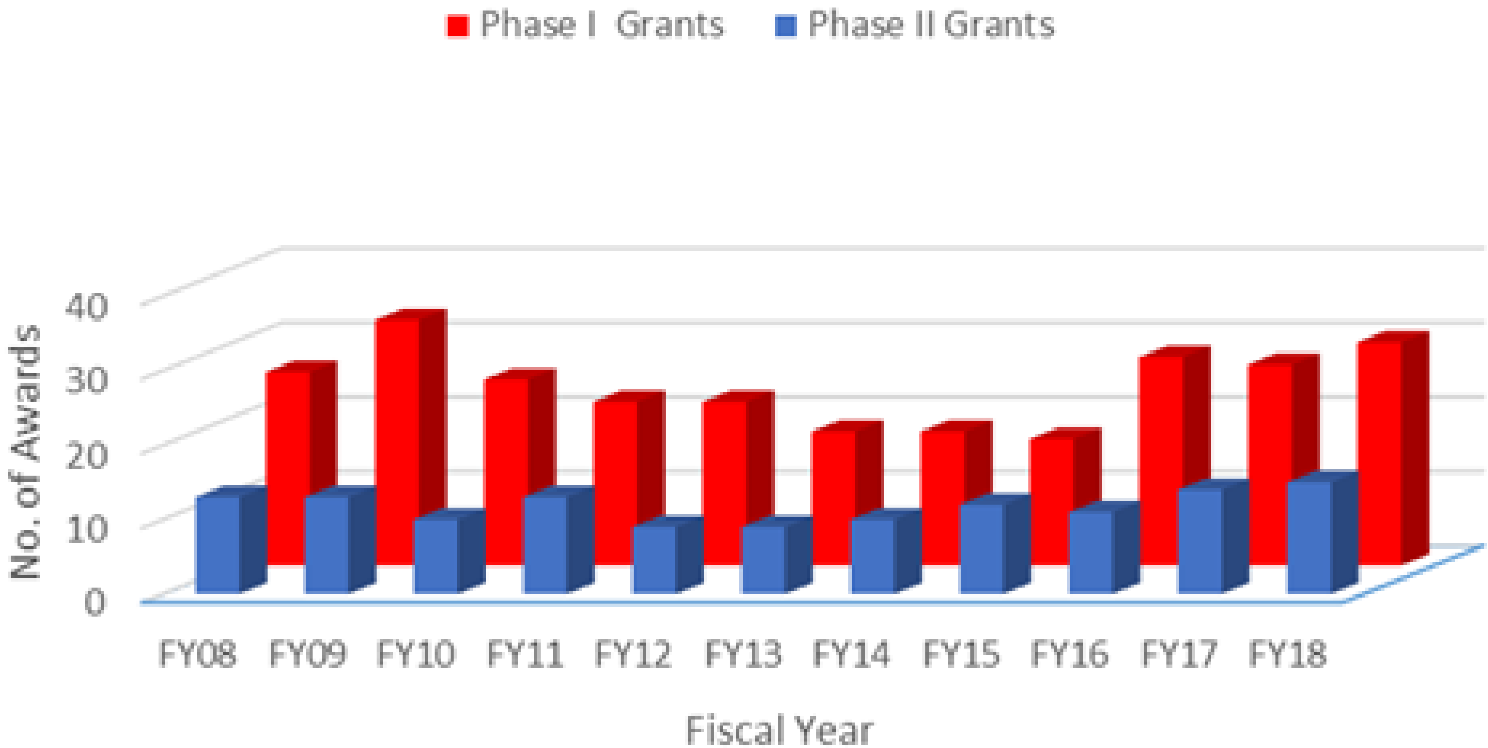
Phase I	Develop a diagnostic tool to non- invasively measure electron spin in particle accelerators.	Electrodynamic	Albuquerque	NM
	Provide the capability to further enhance experiments using rare isotopes.	Reactive Innovations, LLC	Westford	MA
Phase II	This project will exploit recent advances in carbon nanomaterials and low-cost manufacturing techniques to generate carbon foils that can be used current and future accelerators.	Applied Nanotech, Inc.	Austin	TX
	This project will advance digital signal processing electronics to support development of technologies essential to experiments in basic research.	SkuTek Instrumentation	West Henrietta	NY

Phase III Success Stories



https://science.osti.gov/sbir/About

NP SBIR/STTR Award Trend (FY 2008 – FY 2018)



- Total value of grants funded FY 2014 - 2018: ~$81M
- 118 companies benefited from funding (some multiple times) during this time span.
- ~$20 M awarded in FY 2019
- Set aside over 5 years is equivalent to that for a MIE equipment like a detector

Inter-Agency FOA on Nuclear Data is Also Out

DEPARTMENT OF ENERGY
OFFICE OF SCIENCE, NUCLEAR PHYSICS
OFFICE OF SCIENCE, NUCLEAR PHYSICS, ISOTOPES PROGRAM
OFFICE OF NUCLEAR ENERGY
NATIONAL NUCLEAR SECURITY ADMINISTRATION, OFFICE OF DEFENSE NUCLEAR NONPROLIFERATION R&D

….Accordingly, the purpose of the research program associated with this FOA is to support new activities (*e.g.* experiments, infrastructure, models, and so forth) that will provide new nuclear data or related predictions where needed in areas in which the existing data is inadequate or does not exist, and insure that the new data is transferred to the appropriate nuclear databases in a timely manner.

Technical/Scientific Program Contacts:

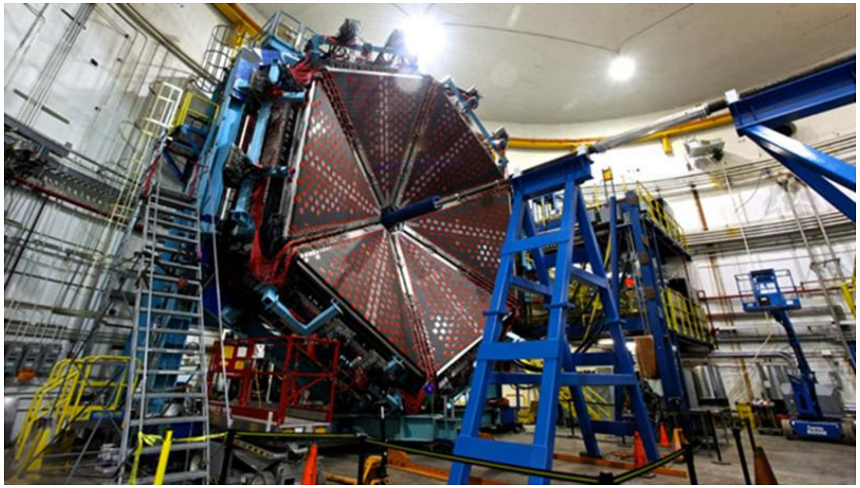
DOE NP:	**Timothy Hallman**	**DOE IP: Ethan Balkin**
DOE NE:	**Dave Henderson**	**DOE NNSA DNN: Donald Hormback**

12 GeV CEBAF Science Program is Underway

CEBAF operates for 32 weeks in FY19

- Recent technical challenges in 17/18 have limited reliability and machine availability. CEBAF ops capped at ~ 26 weeks in FY18.
- Larger investments in maintenance and investments to improve reliability. A larger portion of operations towards cryomodule refurbishment to maintain energy of beam.
- Simultaneous 4-Hall operations.

Hall D Solenoidal Spectrometer



Hall B Time of Flight Detector

Researchers conduct experiments with the 12 GeV CEBAF Upgrade, to:

- Search for exotic new quark-anti-quark particles to advance our understanding of the strong force.
- Find evidence of new physics from sensitive searches for violations of nature's fundamental symmetries.
- Gain a microscopic understanding of the internal structure of the proton, including the origin of its spin, and how this structure is modified when the proton is inside a nucleus.

Medium Research Program (ME)

Initiates, Funds and Supports the Experiments at JLAB/CEBAF in 4 Halls

- **Instrumentation and Detectors**
- **Moller R&D; Detector R&D for SoLID under discussion**
- **Polarized ^{3}He Target for the Super Bigbite Spectrometer**

RHIC Spin Program at BNL/RHIC

Scientific research supporting the Electron Ion Collider

Radium-225 EDM Bluelight upgrade at ANL

Drell-Yan Spinquest (E1039) Experiment at FNAL

MUSE Experiment at PSI

Early Career Awards in ME. FY 2019 NP recipients will announced shortly.

Office Staff and Vacancies

Physics Research Division

Vacant, Division Director

Christine Izzo, Program Support Specialist

- **Medium Energy Nuclear Physics**
  Gulshan Rai
- **Heavy Ion Nuclear Physics**
  Vacant
  Richard Witt (Detailee)
- **Nuclear Structure and Astrophysics**
  Vacant
  Paul Sorensen (IPA)
- **Nuclear Theory**
  George Fai
- **Nuclear Data and Nuclear Theory Computing**
  Vacant
  Fredrik Tovesson (Detailee)
- **Fundamental Symmetries**
  Vacant
  Paul Sorensen (IPA)

al

Facilities & Project Management Division

Jehanne Gillo, Director

Cassie Dukes, Program Analyst

Luisa Romero, Isotope Financial Management Specialist

Latifa Elouadrhiri (Detailee)

- **Advanced Technology R & D**
  Manouchehr Farkhondeh, Deputy
- **Nuclear Physics Instrumentation**
  Elizabeth Bartosz
- **Nuclear Physics Facilities**
  James Sowinski
- **Nuclear Physics Major Initiatives**
  James Hawkins
- **Industrial Concepts**
  Michelle Shinn

- **Isotope Program Operations**
  Marc Garland, Deputy
- **Isotope R&D**
  Ethan Balkin
- **Stable Isotopes**
  Joel Grimm
- **Isotope Accelerator Facilities**
  Arne Freyberger
- **Isotope Reactor Facilities**
  Vacant
- **Other Isotope Facilities**
  Joseph Glaser

March 11, 2019

The SC microsite on Diversity, Equity & Inclusion now posted on the SC website.

The direct link is:

https://science.energy.gov/sc-2/research-and-conduct-policies/diversity-equity-and-inclusion/

"The DOE Office of Science (SC) is fully committed to fostering safe, diverse, equitable, and inclusive work, research, and funding environments that value mutual respect and personal integrity. Effective stewardship and promotion of diverse and inclusive workplaces that value and celebrate a diversity of people, ideas, cultures, and educational backgrounds is foundational to delivering on the SC mission. The scientific community engaged in SC-sponsored activities is expected to be respectful, ethical, and professional.

The DOE SC does not tolerate discrimination or harassment of any kind, including sexual or non-sexual harassment, bullying, intimidation, violence, threats of violence, retaliation, or other disruptive behavior in the federal workplace, including DOE field site offices, or at national laboratories, scientific user facilities, academic institutions, other institutions that we fund, or other locations where activities that we support are carried out…"

Harassment

Harassment of any kind, including sexual and non-sexual harassment, bullying, intimidation, violence, threats of violence, retaliation, or other disruptive behavior is not tolerated in the federal workplace, including Department of Energy (DOE) site offices, or at DOE national laboratories, scientific user facilities, academic institutions, other institutions receiving Office of Science funding, or at locations where activities are funded by the DOE Office of Science.

Harassment includes any unwelcome conduct or reprisal (verbal, written, or physical) that is based on an individual's race, color, sex (including pregnancy, gender identity, and sexual orientation), religion, national origin, age, disability (physical or mental), genetic information, or participation in protected equal employment opportunity (EEO) activities including reporting allegations of harassment or providing information related to harassment allegations.

Harassing behaviors include any unwelcome conduct that: (1) has the purpose or effect of unreasonably interfering with an employee's work performance; (2) creates an intimidating, hostile, or offensive work environment; or (3) affects an employee's employment opportunities or compensation.

Sexual harassment is any unwelcome behavior of a sexual nature including, but not limited to, unwelcome sexual advances, requests for sexual favors (i.e., sexual coercion, including quid pro quo), physical conduct of a sexual nature, or other similar behavior. Sexual harassment also includes verbal and nonverbal behaviors that convey hostility, objectification, exclusion, or second-class status about members of a particular gender (e.g., gender harassment) (NAS 2018). Sexual harassment, like non-sexual harassment, is not always obvious and often subtle.

The Outlook Today

- The U.S. has unquestioned world leadership in experimental QCD research. CEBAF and RHIC are both unique and at the "top of their game" with compelling "must-do" science in progress or about to start. Long term, the future of QCD science is pointing to the need for an electron-ion collider.

- There is a wealth of science opportunity near term at ATLAS, and longer term at FRIB which will be world leading. NP is beginning to position the low energy experimental community to take full advantage of FRIB. The Theory Alliance (and support for theory in general) is also crucial.

- A very high priority for the NP community is U.S. leadership in the science of neutrino-less double beta decay.

  - A specific challenge will be ensuring essential R&D for candidate technologies is completed in the next 2-3 years prior to a down-select for a ton-scale experiment

- Research and production efforts to meet the Nation's need for isotopes in short supply are being strengthened; re-establishing U.S. capability for stable isotopes will be a major advance and will help address community concerns in this area documented in the 2009 and 2015 NSAC-I Strategic Plans

The Outlook Today

- Quantum Information Science

  New investments in QIS research will exploit quantum phenomena to allow new ways to measure, process, and transmit information for application at the interface of Nuclear Physics including quantum computing, quantum simulations and sensing. QIS technologies offer the ability to discover and probe the fundamental structure and behavior of Nature with unprecedented sensitivity and accuracy.

- Artificial Intelligence and Machine Learning

  New investments could be used to explore data analytics and machine learning techniques for accelerator optimization, control, prognostics, and data analysis. The immense computing and data challenges of nuclear physics are ideally suited to modern machine-learning algorithms.

General Outlook

- The experience with FY18 and FY19 budgets has required readiness for big swings in the budget. FY2020 may be similar.

- We need to stay focused and continue to deliver important outcomes for the nation.

- Delivering exciting discoveries, important scientific knowledge, technological advances, and workforce training is what we do.

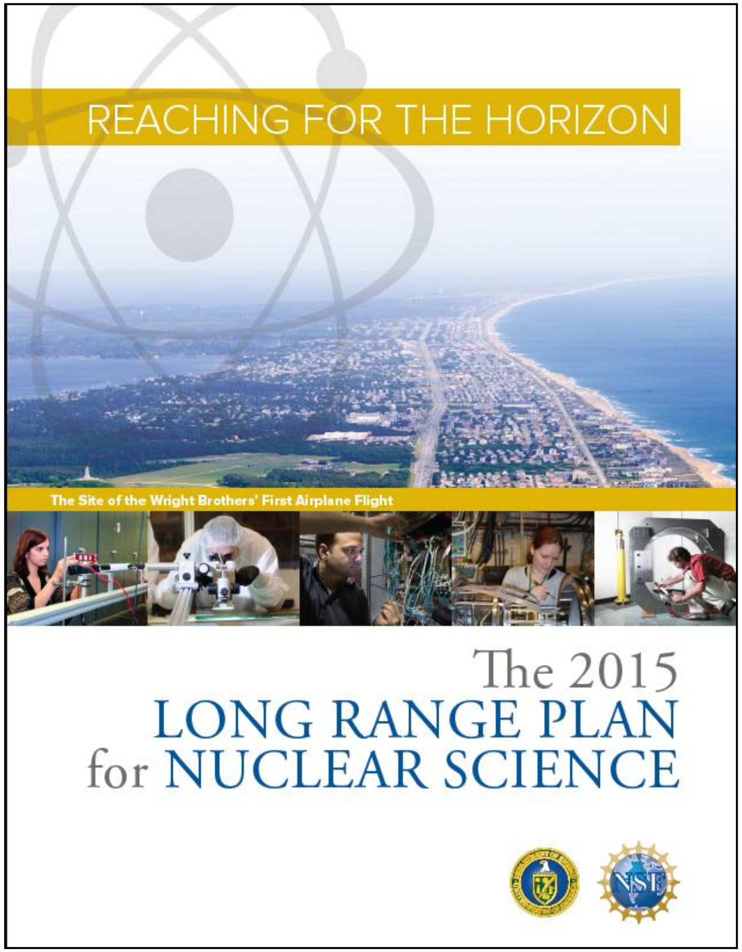
- We need to keep up the good work!

Additional

The 2015 Long Range Plan for Nuclear Science

Recommendations:

1. Capitalize on investments made to maintain U.S. leadership in nuclear science.
2. Develop and deploy a U.S.-led ton-scale neutrino-less double beta decay experiment.
3. Construct a high-energy high-luminosity polarized electron-ion collider (EIC) as the highest priority for new construction following the completion of FRIB.
4. Increase investment in small-scale and mid-scale projects and initiatives that enable forefront research at universities and laboratories.



The FY2020 Request allows NP to continue to pursue aspects of the 2015 LRP Vision

Nuclear Physics Scientific Thrusts

Nuclear physics addresses three broad, yet tightly interrelated, scientific thrusts: **Quantum Chromodynamics (QCD)**; **Nuclei and Nuclear Astrophysics**; and **Fundamental Symmetries**:

- **QCD** seeks to develop a complete understanding of how the fundamental particles that compose nuclear matter, the quarks and gluons, assemble themselves into composite nuclear particles such as protons and neutrons, how nuclear forces arise between these composite particles that lead to nuclei, and how novel forms of bulk, strongly interacting matter behave, such as the quark-gluon plasma that formed in the early universe.
- **Nuclei and Nuclear Astrophysics** seeks to understand how protons and neutrons combine to form atomic nuclei, including some now being observed for the first time, and how these nuclei have arisen during the 13.8 billion years since the birth of the cosmos.
- **Fundamental Symmetries** seeks to develop a better understanding of fundamental interactions by studying the properties of neutrons and by performing targeted, single focus experiments using nuclei to study whether the neutrino is its own anti-particle. Neutrinos are very light, nearly undetectable fundamental particles produced during interactions involving the weak force, through which they were first indirectly observed in nuclear beta decay experiments.

FY2020 Budget Request

Nuclear Physics
Funding

	(dollars in thousands)			
	FY 2018 Enacted	**FY 2019 Enacted**	**FY 2020 Request**	**FY 2020 Request vs FY 2019 Enacted**
Medium Energy Nuclear Physics				
Research	40,050	43,286	35,500	-7,786
Operations	112,000	117,390	114,500	-2,890
Other Research	4,152	3,553	2,667	-886
SBIR/STTR	19,248	19,961	18,633	-1,328
Total, Medium Energy Nuclear Physics	**175,450**	**184,190**	**171,300**	**-12,890**
Heavy Ion Nuclear Physics				
Research	40,050	37,354	30,000	-7,354
Operations	187,500	193,125	186,000	-7,125
Total, Heavy Ion Nuclear Physics	**227,550**	**230,479**	**216,000**	**-14,479**
Low Energy Nuclear Physics				
Research	66,500	70,530	58,450	-12,080
Operations	29,250	30,215	36,838	+6,623
Total, Low Energy Nuclear Physics	**95,750**	**100,745**	**95,288**	**-5,457**
Nuclear Theory				
Theory Research	38,750	46,469	37,040	-9,429
Nuclear Data	8,600	8,858	7,726	-1,132
Other Project Costs	—	—	1,500	+1,500
Total, Nuclear Theory	**47,350**	**55,327**	**46,266**	**-9,061**
Isotope Development and Production for Research and Applications				
Research	11,000	9,808	12,000	+2,192
Operations	29,700	34,451	39,000	+4,549
Total, Isotopes[a]	**40,700**	**44,259**	**51,000**	**+6,741**
Subtotal, Nuclear Physics	**586,800**	**615,000**	**579,854**	**-35,146**

FY2020 SC Budget Request Continued

(dollars in thousands)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Construction				
14-SC-50, Facility for Rare Isotope Beams	97,200	75,000	40,000	-35,000
20-SC-51, U.S. Stable Isotope Production and Research Center	—	—	5,000	+5,000
Total, Nuclear Physics	**684,000**	**690,000**	**624,854**	**-65,146**

SBIR/STTR Funding:

- FY 2018 Enacted: SBIR $16,875,000 and STTR $2,373,000
- FY 2019 Enacted: SBIR $17,500,000 and STTR $2,461,000
- FY 2020 Request: SBIR $16,336,000 and STTR $2,297,000

FY 2020 Budget Request Capital Equipment

Nuclear Physics
Capital Equipment

(dollars in thousands)

	Total	Prior Years	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Capital Equipment						
Major Items of Equipment (MIE)						
Medium Energy Nuclear Physics						
MOLLER MIE	25,000-35,000	N/A	N/A	—	300	+300
Heavy Ion Nuclear Physics						
Super-PHENIX (sPHENIX) MIE[a]	24,200-34,500	N/A	N/A	5,310	3,000	-2,310
Low Energy Nuclear Physics						
Gamma-Ray Energy Tracking Array (GRETA) MIE	52,000–65,000[b]	N/A	5,200	6,600	2,500	-4,100
High Rigidity Spectrometer (HRS)[c]	80,000-90,000	N/A	N/A	—	1,000	+1,000
Neutrinoless Double Beta Decay MIE	215,000-250,000	N/A	N/A	—	1,440	+1,440
Isotope Development and Production for Research and Development						
Stable Isotope Production Facility (SIPF) MIE	25,500–28,000	N/A	10,000	11,500	1,500	-10,000
Total Non-MIE Capital Equipment	N/A	N/A	7,202	14,615	7,678	-6,937
Total, Capital Equipment	**N/A**	**N/A**	**22,402**	**38,025**	**17,418**	**-20,607**

FY 2020 Budget Request Minor Construction Activities

Nuclear Physics
Minor Construction Activities

(dollars in thousands)

	Total	Prior Years	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
General Plant Projects						
Greater than or equal to $5M and less than $20M						
End Station Refrigerator at TJNAF	9,500	—	—	—	9,500	+9,500
Total GPPs, greater than or equal to $5M and less than $20M	9,500	—	—	—	9,500	+9,500
Total GPPs less than $5M[a]	N/A	N/A	2,000	2,060	—	-2,060
Total, General Plant Projects (GPP)	**N/A**	**N/A**	**2,000**	**2,060**	**9,500**	**+7,440**
Accelerator Improvement Projects (AIP)						
Greater than or Equal to $5M and less than $20M						
RHIC Low Energy Electron Cooling	8,300	7,000	1,300	—	—	—
FRIB Isotope Harvesting[b]	9,000-11,000	N/A	N/A	—	2,000	+2,000
Total AIPs (greater than or equal to $5M and less than $20M)	N/A	N/A	1,300	—	2,000	+2,000
Total AIPs less than $5M	N/A	3,652	3,629	5,077	4,929	-148
Total, Accelerator Improvement Projects	**N/A**	**10,652**	**4,929**	**5,077**	**6,929**	**+1,852**
Total, Minor Construction Activities	**N/A**	**N/A**	**6,929**	**7,137**	**16,429**	**+9,292**

FY 2020 Budget Request Construction Projects

Nuclear Physics
Construction Projects Summary

(dollars in thousands)

	Total	Prior Years	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
14-SC-50, Facility for Rare Isotope Beams						
DOE TPC	635,500[a]	418,000[b]	97,200	75,000	40,000	-35,000
20-SC-51, U.S. Stable Isotope Production and Research Center						
TPC	150,000-200,000	—	—	—	5,000	+5,000
Total, Construction (TPC)	**N/A**	**N/A**	**97,200**	**75,000**	**45,000**	**-30,000**

Funding Summary

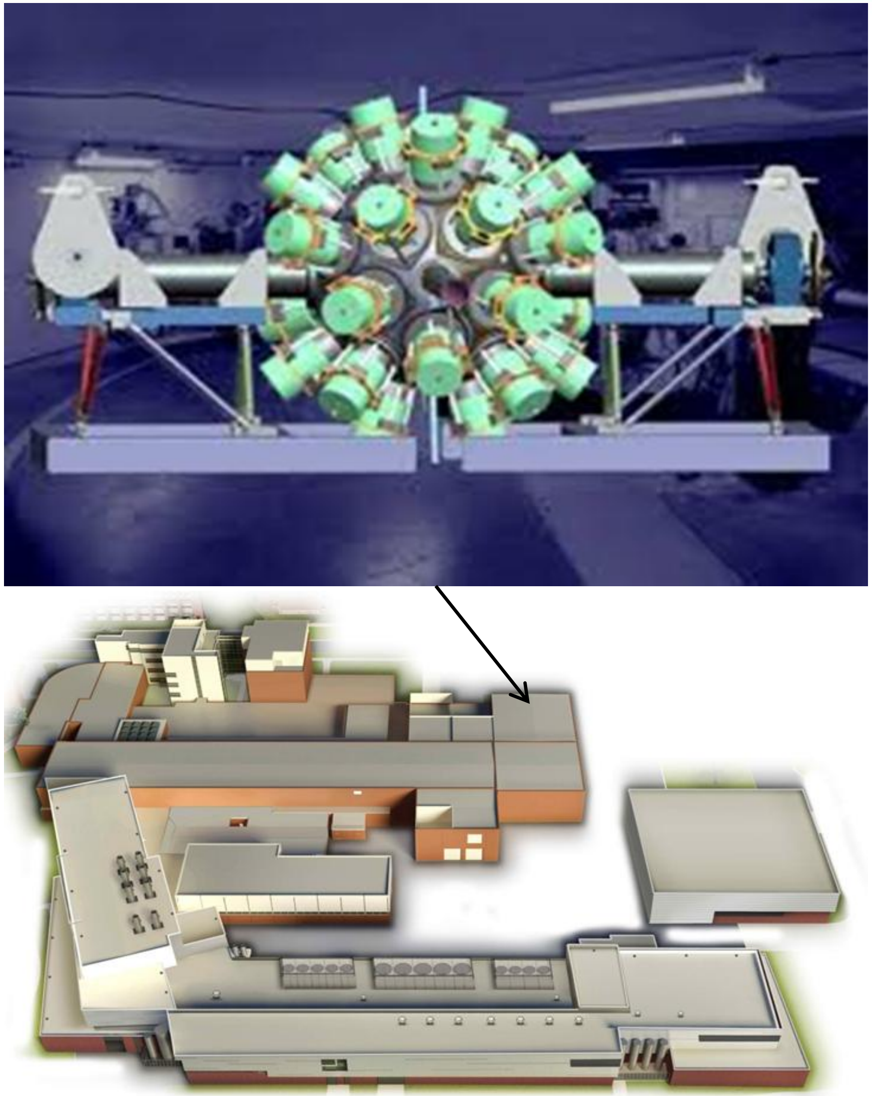
(dollars in thousands)

	FY 2018 Enacted	FY 2019 Enacted	FY 2020 Request	FY 2020 Request vs FY 2019 Enacted
Research	180,502	204,095	172,476	-31,619
Scientific User Facilities Operations	324,250	336,145	333,038	-3,107
Other Facility Operations	24,200	27,586	41,800	+14,214
Projects (includes Other Project Costs)				
Major Items of Equipment	15,200	23,410	9,740	-13,670
Facility for Rare Isotope Beams	97,200	75,000	40,000	-35,000
U.S. Stable Isotope Production and Research Center	—	—	5,000	+5,000
Electron Ion Collider (OPC)	—	—	1,500	+1,500
Total, Projects	112,400	98,410	56,240	-42,170
Other[c]	23,400	23,764	21,300	-2,464
Total, Nuclear Physics	**684,000**	**690,000**	**624,854**	**-65,146**

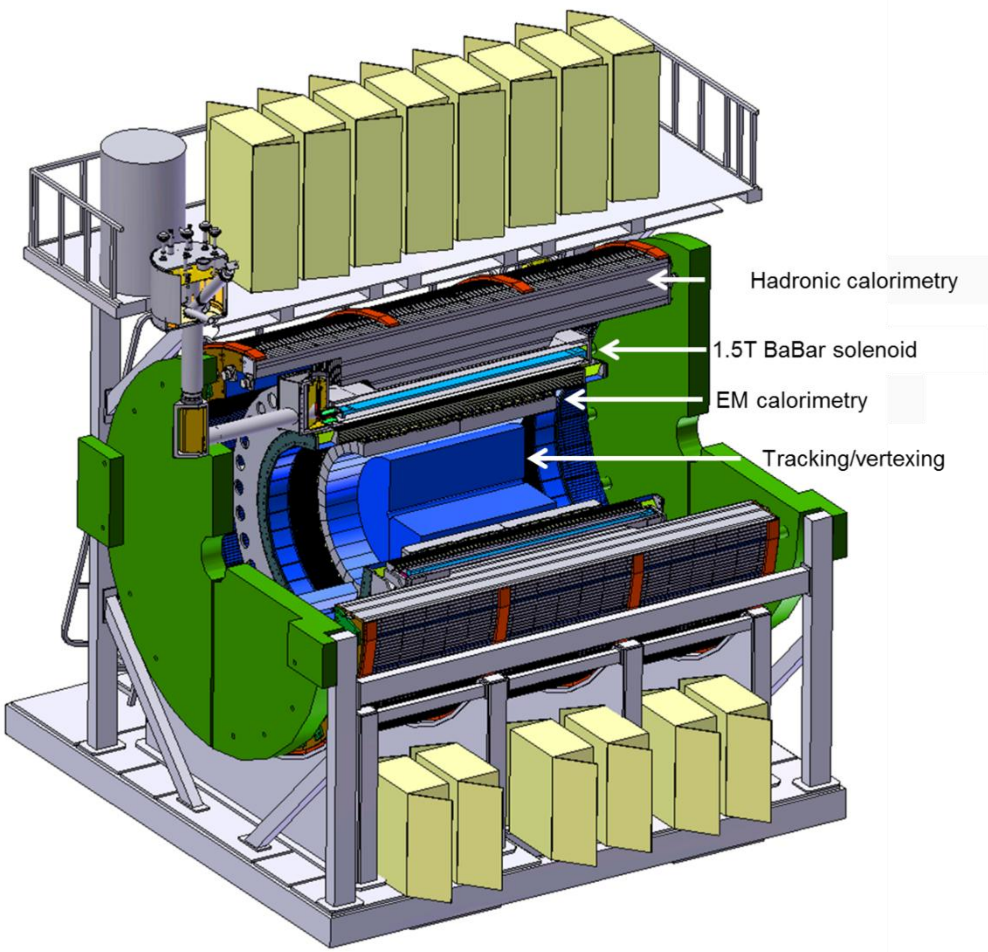
Ongoing MIEs that continue in the FY2020 Request

Fabrication of the Gamma-Ray Energy Tracking Array (GRETA) for FRIB Continues

- The Gamma Ray Energy Tracking Array (GRETA) is a Major Item of Equipment (MIE) initiated in FY 2017: a premiere gamma-ray tracking device that will exploit the new capabilities of FRIB.
- GRETA was identified by NSAC as an instrument that will “revolutionize gamma-ray spectroscopy and provide sensitivity improvements of several orders of magnitude.”
- GRETA will advance the rare-isotope science at FRIB and investigate reactions of importance for nuclear structure and nuclear astrophysics.
- GRETA Progress continues
- Est. Total Project Cost: $52M-$65M
- $2.5M included in the FY2020 Request



Within Available Funds, the sPHENIX Upgrade is Continued



August 16, 2018: CD-1 and CD-3a for long lead procurements

$3M included in the FY2020 Request

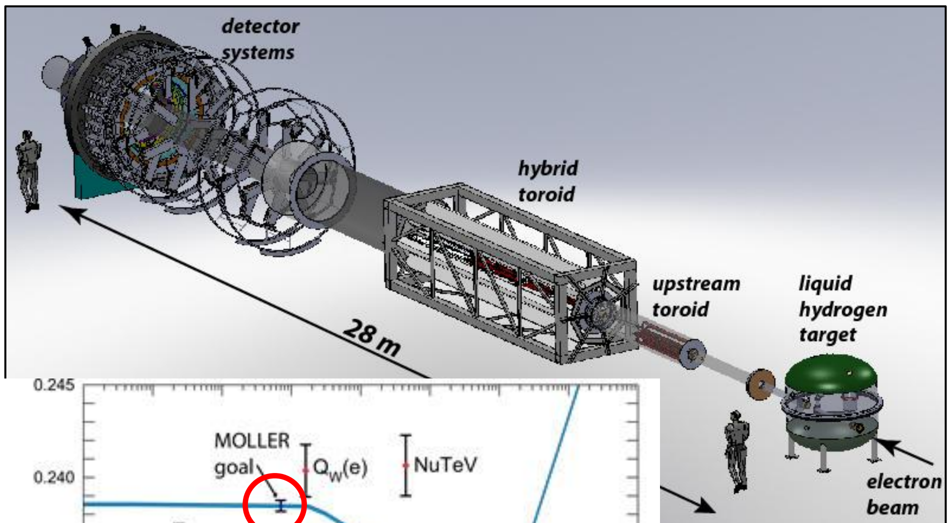
- mapping the character of the hadronic matter under extreme conditions by varying the temperature of the medium, the virtuality of the probe, and the length scale within the medium.
- understanding the parton–medium interactions by studying heavy-flavor jets.
- probing the effect of the quark–gluon plasma on the Upsilon states by comparing the p-p (proton-proton), p-A (proton-nucleus), and A-A (nucleus-nucleus) collisions.

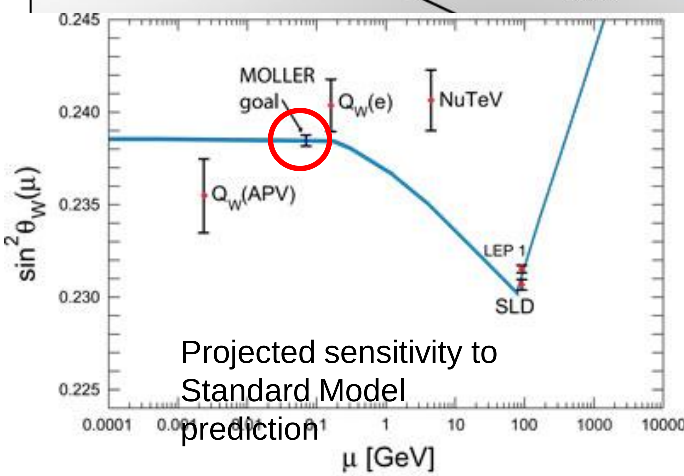
Implemented from within RHIC base by limiting operations to one detector and periodically not operating facility.

New Starts Included in the FY2020 Request

MOLLER: a “Must Do” Experiment To Point the Way to New Science

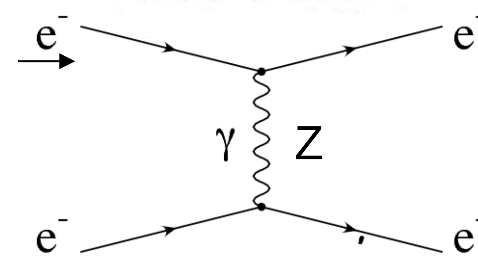
The scientific world rather desperately needs additional markers due to the consistency thus far of LHC data with Standard Model Predictions. Due to the technical challenge of constructing a next generation accelerator with very high accelerating gradients, those markers will have to come from “indirect” discovery experiments like MOLLER.





Projected sensitivity to Standard Model prediction

parity-violating
Moller scattering
$\vec{e} + e \rightarrow e + e$



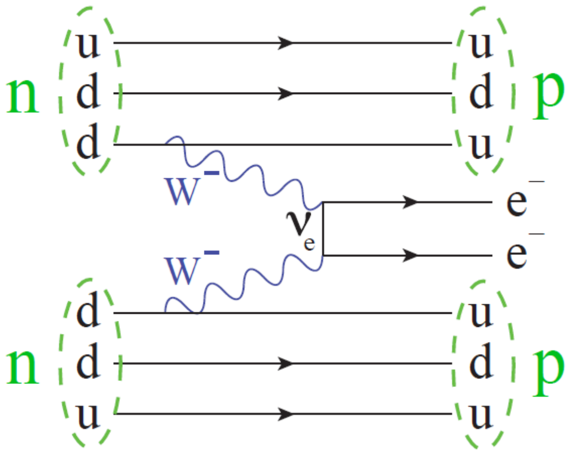
In MOLLER, polarized electrons are scattered of unpolarized electrons. The amount of parity violation due to interference of the two possible exchange mechanisms (γ or Z) is <u>precisely</u> predictable in QED. (No messy quarks or color charge, or QCD to worry about, only quantum electrodynamics). The theory is so “clean” that like the g-2 approach, If the level of parity violation is greater than expected, a new particle must be the source of the discrepancy.

Has CD0, TEC funding of $300k Included in the FY2020 Request

R&D "Demonstrators" Leading Up to a Ton-Scale 0νββ Decay Experiment

How can it be determined whether the neutrino is a Majorana Particle?

Search for Neutrino-less Double Beta Decay (0νββ): in a selected nucleus, two neutrons decay into two protons and two electrons, with no neutrinos being emitted.



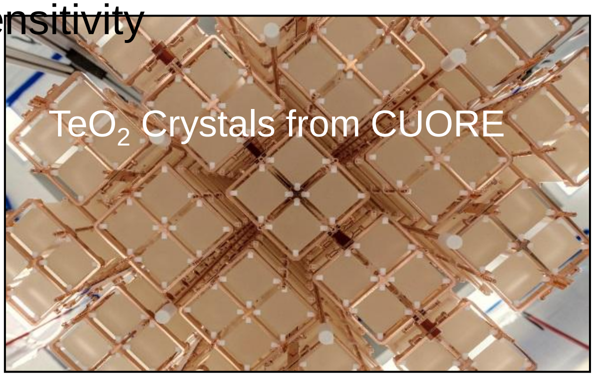
It can only happen if the two neutrinos from the two W⁻ particles annihilate internally because the neutrino is its own anti-particle

DOE NP

DOE HEP

Support through demonstrator phase

Scientists have been eagerly working to demonstrate the necessary sensitivity



TeO_2 from CUORE and CUOREcino
1.5 × 10^{25} years, 90% CL

Ge^{76} from Majorana Demonstrator
1.9 × 10^{25} years, 90% CL

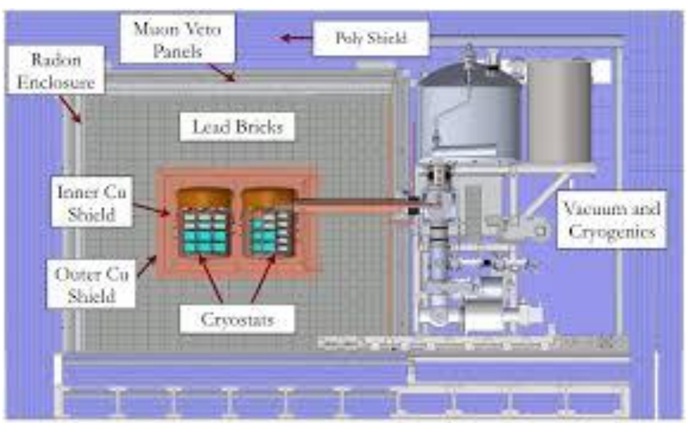
Ge^{76} from GERDA
8.0 × 10^{25} years, 90% CL

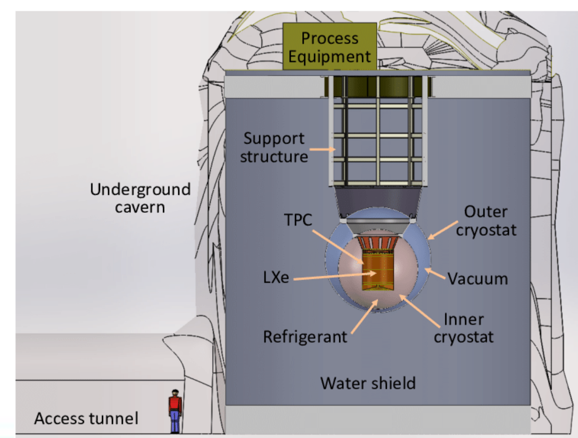
Xe^{136} from EXO-200
1.8 × 10^{25} years, 90% CL

Xe^{136} from Kamland-Zen
1.1 × 10^{26} years, 90% CL

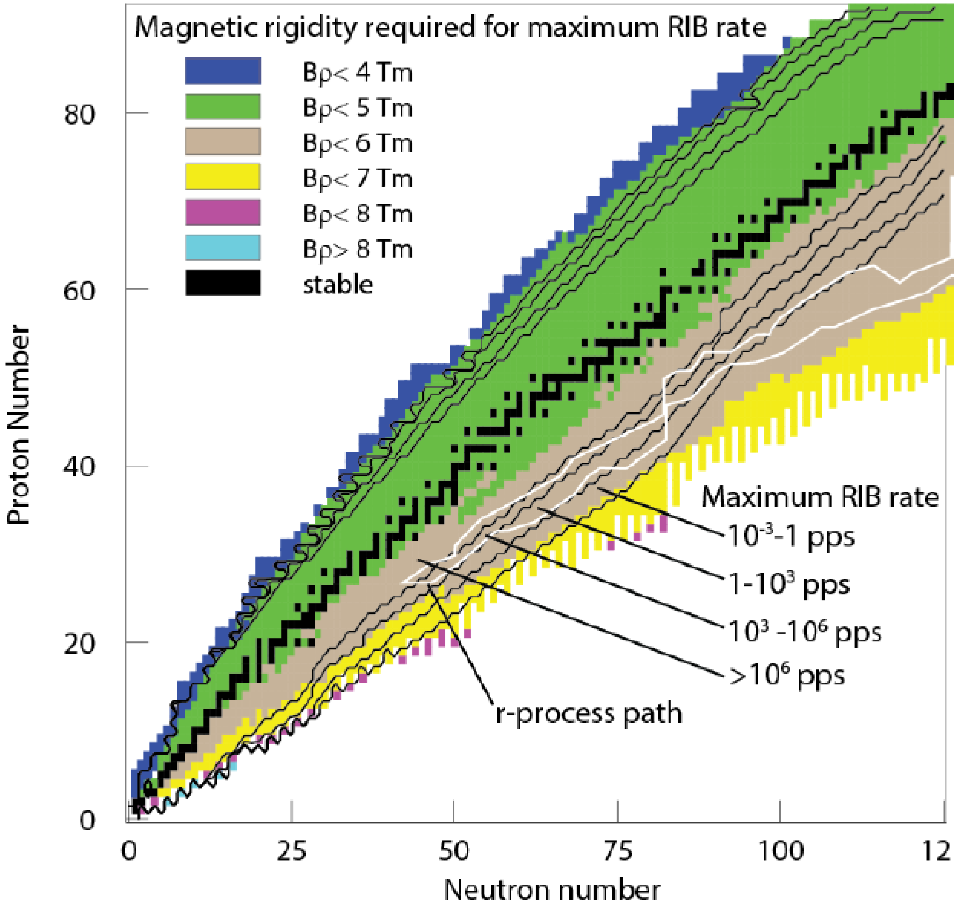
Current Status

- Critical Decision – 0, Mission Need, approved in November 2018
- TEC construction start for a ton-scale $0\nu\beta\beta$ experiment requested in the FY2020 President's Budget Request. TEC Funding of $1.44M Requested.
- Meeting is planned on the margins of IUPAP WG9 Meeting in London (8/2019) to discuss possible international collaboration
- Processes for technology down-select and site selection for a 1 ton experiment are under discussion:
  - Three major candidate experiments, LEGEND-1000 (Ge-76), CUPID (Mo-100), nEXO (Xe-136).
  - Three main candidate site locations: Gran Sasso (Italy), SNOLAB (Canada) and SURF (U.S)





The Need For a High Rigidity Spectrometer (HRS) at FRIB



By design, the day-1 physics program will make use of existing NSCL infrastructure. The S800 and Sweeper Spectrometers currently available at NSCL have magnetic rigidity (bending power) limits of 4 Tesla-Meters

The magnetic rigidity for achieving the maximum rare isotope beam intensity is greater than 4 Tesla-meters for almost all species produced at FRIB and ranges up to 8 Tesla-meters for the most neutron rich rare isotopes

The regions most interesting for research on heavy element production in the cosmos (the nuclei with maximum neutrons) needs almost 8 T-m. Current NSCL instrumentation limit is 4 T-m so, upgraded capability is required

Has CD0, TEC Funding of $1.0M Requested in FY2020

More Additional Information

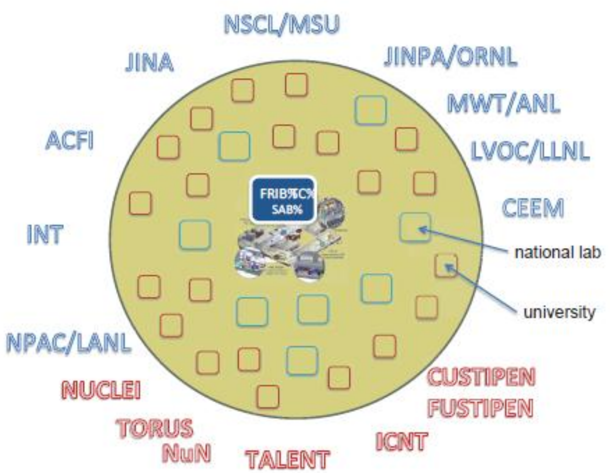
Nuclear Theory

Maintaining adequate support for a robust nuclear theory effort is essential to the productivity and vitality of nuclear science

A strong Nuclear Theory effort:

- Poses scientific questions and presents new ideas that potentially lead to discoveries and the construction of facilities.
- Helps make the case for, and guide the design of new facilities, their research programs, and their strategic operations plan.
- Provides a framework for understanding measurements made at facilities and interprets the results.

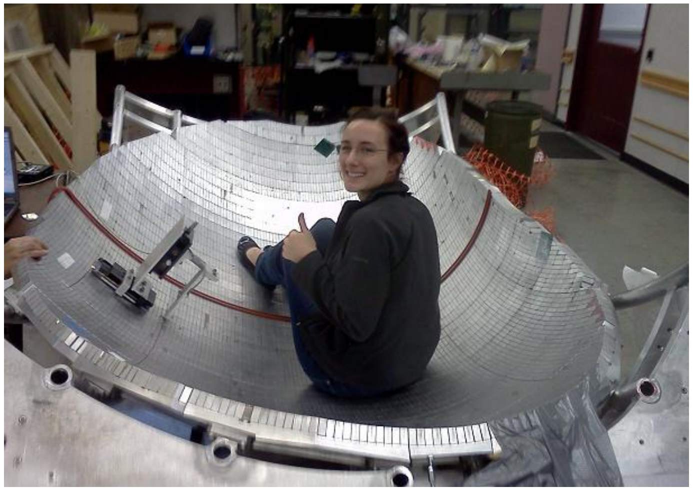
- In FY20, 4 fixed-term, multi-institution Theory Topical Collaborations are continued to investigate specific topics
- The FRIB Theory Alliance is continued
- LQCD computing is restored
- Funding maintains support for SciDAC-4 projects that received 5-year awards starting in FY17



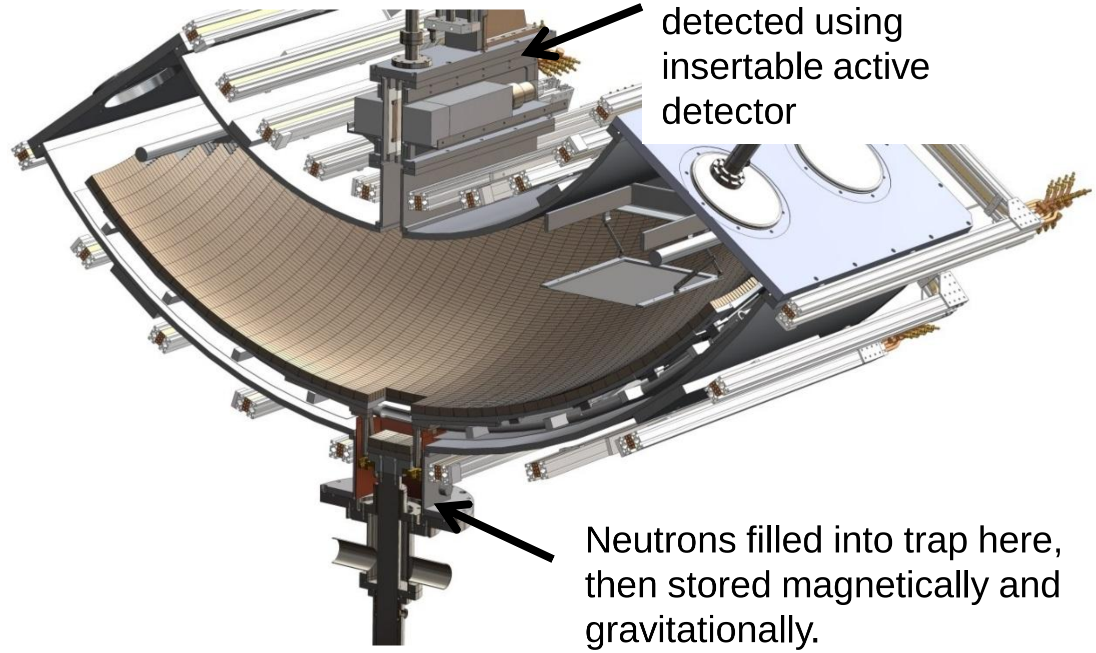
FRIB Theory Alliance

An Important "Other Low Energy" Advance from UCNtau

The UCNτ experiment testbed is operational and acquiring data to study systematic effects.



Cubic meter trap stores tens of thousands of neutrons per fill, allowing rapid study of small effects.



Surviving neutrons detected using insertable active detector

Neutrons filled into trap here, then stored magnetically and gravitationally.

Key features of experiment:

1) Magnetic bottle has storage time much greater than free neutron lifetime, rapid phase space mixing
2) Rapid internal neutron detection scheme counts surviving neutrons with constant efficiency
3) No absolute counting efficiencies needed: only relative neutron counting

A Breakthrough Neutron Lifetime Experiment

Measurement of the neutron lifetime using a magneto-gravitational trap and in situ detection

R. W. Pattie Jr.[1], et al.

Science 11 May 2018:
Vol. 360, Issue 6389, pp. 627-632

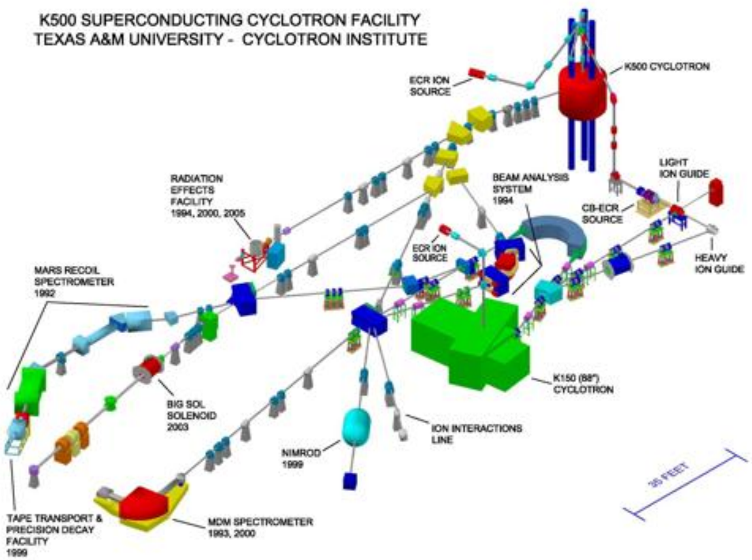
Abstract

The precise value of the mean neutron lifetime, τ_n, plays an important role in nuclear and particle physics and cosmology. It is used to predict the ratio of protons to helium atoms in the primordial universe and to search for physics beyond the Standard Model of particle physics. We eliminated loss mechanisms present in previous trap experiments by levitating polarized ultracold neutrons above the surface of an asymmetric storage trap using a repulsive magnetic field gradient so that the stored neutrons do not interact with material trap walls. As a result of this approach and the use of an in situ neutron detector, the lifetime reported here [877.7 ± 0.7 (stat) +0.4/–0.2 (sys) seconds] does not require corrections larger than the quoted uncertainties.

Two NP Centers of Excellence at TUNL and Texas A&M

1967 - 2017 50 YEARS OF BEAM exploring the nuclear frontier

CYCLOTRON INSTITUTE
TEXAS A&M UNIVERSITY

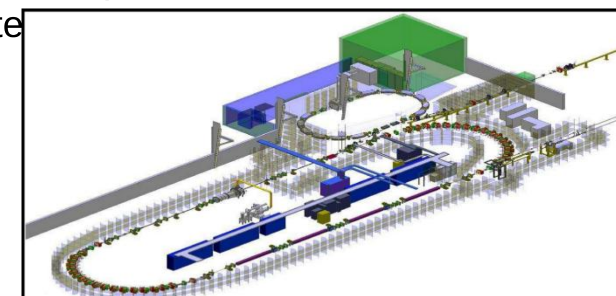


The Texas A&M University Cyclotron Institute jointly supported by DOE and the State of Texas focuses on conducting basic research, educating students in accelerator-based science and technology, and providing technical capabilities for a wide variety of applications in space science, materials science, analytical procedures and nuclear medicine.

The 88 inch cyclotron also plays a crucial role in space radiation effects chip testing for the Air Force

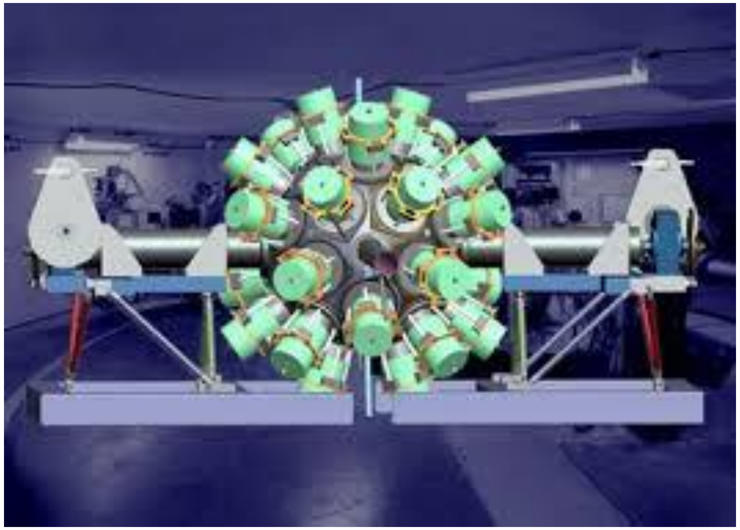
TUNL TRIANGLE UNIVERSITIES NUCLEAR LABORATORY
Durham, North Carolina
A US Department of Energy Center of Excellence in Nuclear Physics

The Triangle Universities Nuclear Laboratory (TUNL) is Center of Excellence that focuses on low-energy nuclear physics research. TUNL is a consortium Duke University, North Carolina State University, and the University of North Carolina at Chapel Hill comprising about 30 faculty members, 20 postdocs and research scientists, and 50 graduate

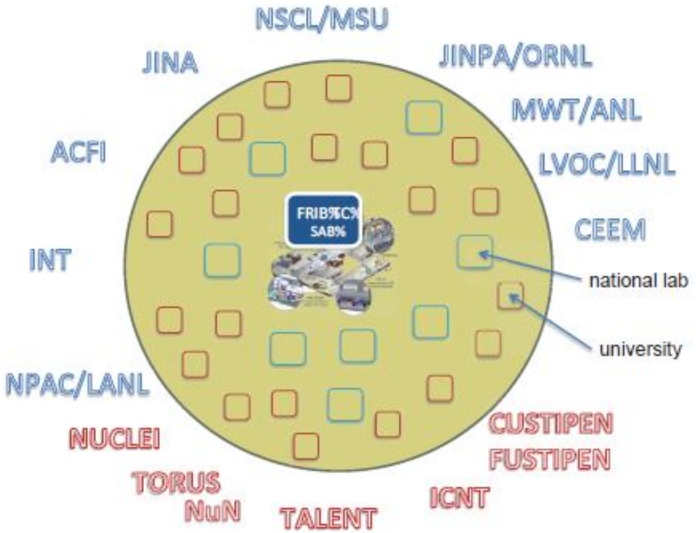


U.S. DEPARTMENT OF ENERGY | Office of Science

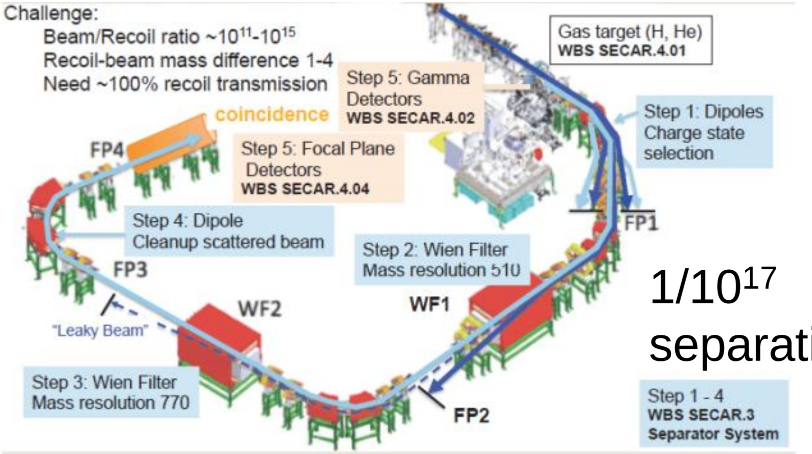
FRIB Instrumentation/Theory Effort Are Underway



GRETA CD3a 8/2018

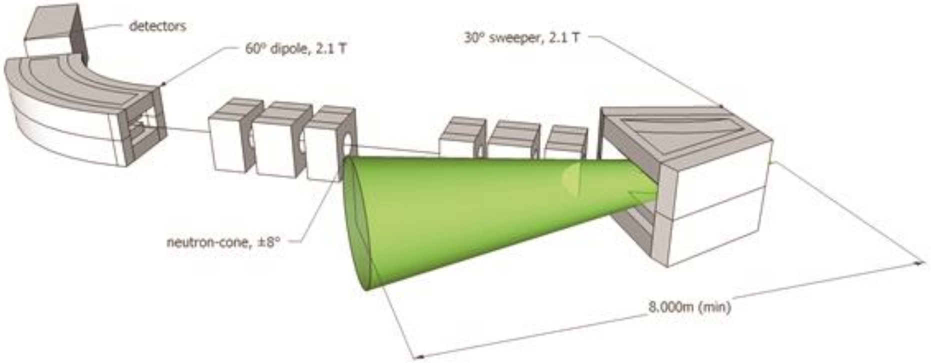


FRIB Theory Alliance



$1/10^{17}$ separation

SECAR Complete FY20/21

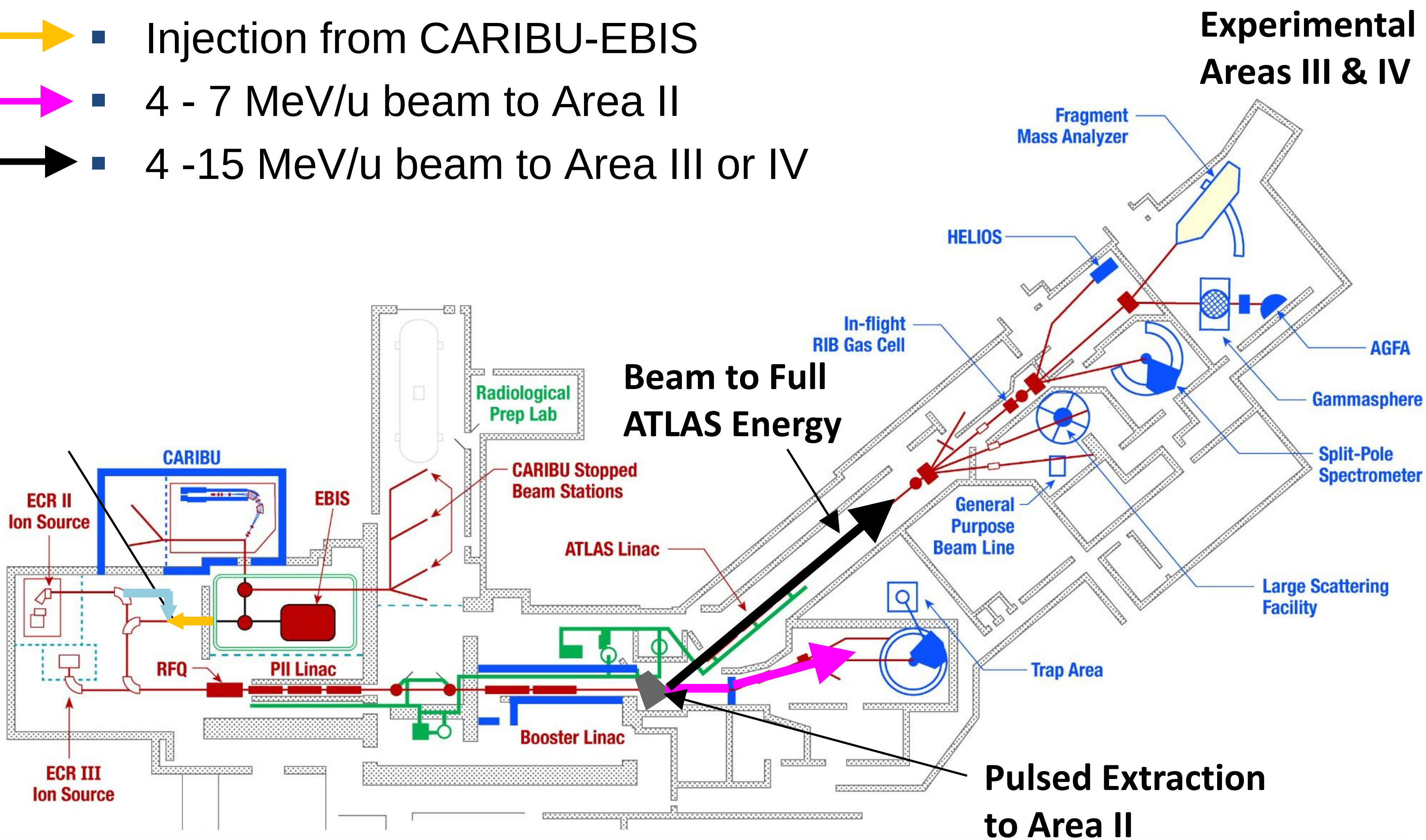


Pre-Conceptual High Rigidity Spectrometer (HRS)

U.S. DEPARTMENT OF ENERGY | Office of Science

Scope of the Proposed Multi-User Upgrade AIP

- Injection from ECR
- Injection from CARIBU-EBIS
- 4 - 7 MeV/u beam to Area II
- 4 -15 MeV/u beam to Area III or IV

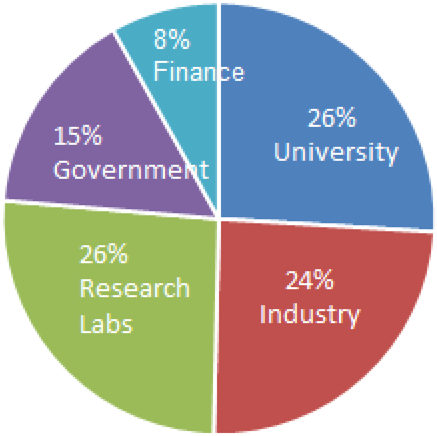


How An NP Trained Workforce Benefits the Nation

Where Do the Entrants into Industry Go?

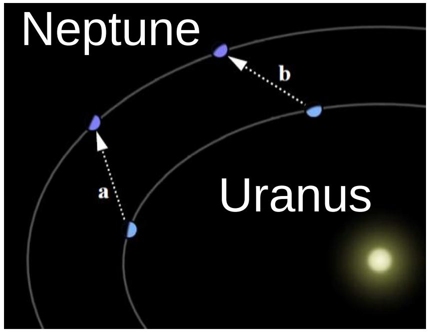
Data scientist at a company that develops software for predictive maintenance of machines
Chemist at a European large home fragrance company
Research Scientist at a mining technology company
Sr. technical staff at an international internet-of-things company
Sr. Chemist at a mining company
Sr. Research Scientist at a Fotune-100 conglomerate
Founder of a cloud company and Founder/General Partner of a venture capital firm
Sr. Scientist at an international optics company
Head of bioinformatics at a molecular therapy company
Director of Radiological Product Development of a global healthcare technology company
Scientist at a global image sensor company
Vice President of Engineering of a software application development company
Chief Researcher at an international industrial research lab
Director of Innovation at a popular data science platform company
Scientific Translator and Editor
Senior Manager at a EU-listed company that provides microstructuring equipment for the semiconductor industry.
Software engineer at an international computer game company, specializing in physics simulations for games.
Technical Lead of a NYSE-listed company that provides high-speed data movement interconnects
Accelerator and materials technical lead at the radiation effects laboratory of a major Fortune-50 aerospace company.
Owner of a private technology/consulting company

Case Study of an
NP supported Experiment



The Experimental Discovery Strategy Behind MOLLER

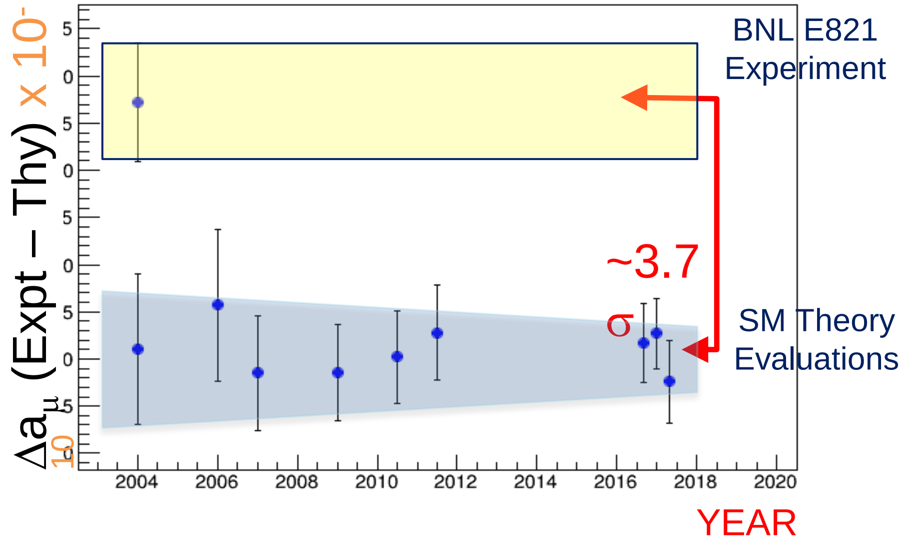
An “old-school” analogy to the experimental approach in MOLLER: --indirect observation and discovery of Neptune.



Neptune could not be seen because of its distance, but its gravitational effects on Uranus could be, and because the theory of Newtonian gravity was precise, it was inescapable that another planet must exist at a location that was predictable.

In the search for new physics, the same approach can be used. In this case the theory is quantum electro-dynamics (QED) (not gravity), but if a deviation from theory is observed, there must be another “hidden” particle interacting with the known ones. A key to the success of this technique is that QED is the only theory that applies, and after years of refinement, it is one of the most precise theories in science

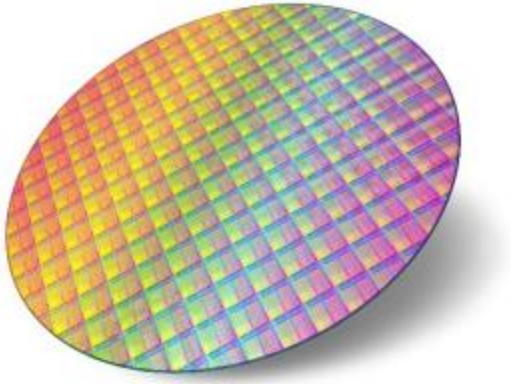
The strongest current experimental scientific “marker” that implies new science beyond our present understanding is the g-2 result measured at BNL. It is currently being repeated at FNAL. It relies on the fact that the rotation of a charged particle with spin in a magnetic field should be exactly predictable via QED unless other particles--thus far invisible--are interacting with the known rotating particle.



DOE/SC QIS PI Meeting

- **Held January 31-February 1, 2019**
- **267 attendees with PIs and observers from all SC programs and observers from other Federal Agencies**
- **Plenary speakers included Jake Taylor, OSTP; John Preskill, Caltech; Irfan Siddiqi, LBNL; and David Awschalom, ANL/University of Chicago**
- **Topical Breakout Discussion sessions**
    - Quantum computing for application-specific research: Machine learning, data analysis, and related topics
    - Foundational quantum physics and information theory
    - Quantum qubits and computing platforms
    - Advanced synthesis and characterization tools (including validation)
    - Computer science and applied math challenges for quantum computing
    - Quantum sensors and detectors
    - Quantum computing for application-specific research: Chemistry, materials, variational techniques, field theories
    - Analog simulations and quantum simulation experiments
- **SC Program Office Breakout discussions**
- **Lightning round of Quantum Center Pitches**

BES Microelectronics Research



- Semiconductor-based microelectronics are critical to the U.S. economy, scientific advancement, and national security.
- High-performance computing underpins DOE missions and future computing technologies (e.g., quantum, neuromorphic, probabilistic, etc.) hold promise for next-generation DOE mission applications.
- The multi-decade success of Moore’s Law has been driven by innovation.
- Additional innovation is needed to keep up with dramatic market growth and to meet future national needs; alternative materials, devices, fabrication techniques and architectures are likely to result.

FY 2020 Plans

- BES will expand core research and the EFRCs in 2020, placing an emphasis on materials and chemical science challenges that are relevant to advanced microelectronics.
- Research priorities will be guided by the Basic Research Needs for Microelectronics workshop.

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