U.S. DEPARTMENT OF ENERGY | Office of Science

Perspectives from DOE Nuclear Physics (NP)

NSAC Meeting
March 2, 2020

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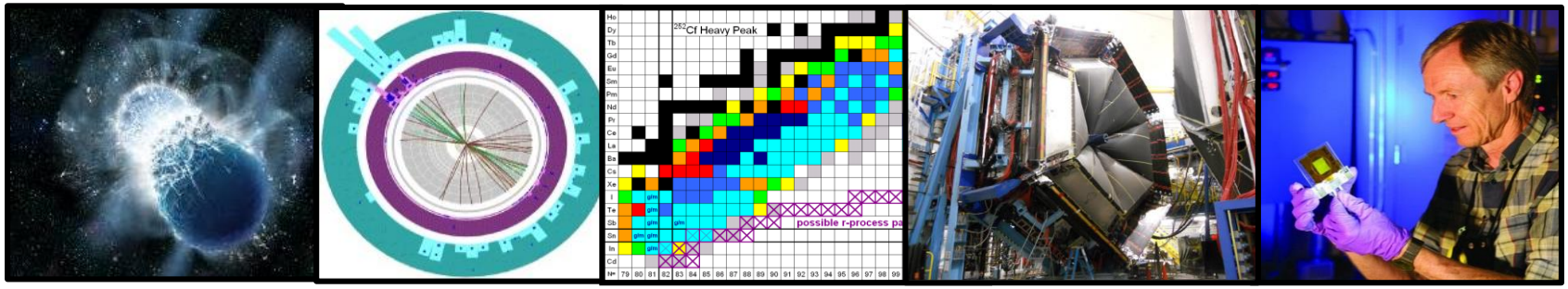


Nuclear Physics FY2020 Budget Status

Nuclear Physics	FY 2019 Enacted	FY2020 Enacted
Operations and maintenance		
Medium Energy	184,994	189,089
TJNAF Ops	*118,440*	*123,610*
Heavy Ions	227,625	232,362
RHIC Ops	*191,771*	*195,151*
Low Energy	101,896	127,037
ATLAS Ops	*22,746*	*22,839*
FRIB Ops	*3,950*	*28,500*
Nuclear Theory	56,226	52,012
Isotope Program	44,259	49,500
EIC OPC Funding	-	10,000
Total, Operations and maintenance	**615,000**	**660,000**
Construction		
14-SC-50 Facility for Rare Isotope Beams	75,000	40,000
21-SC-52, Electron Ion Collider	-	1,000
20-SC-51, U.S. Stable Isotope Production and Research Center	-	12,000
Total, Construction	**75,000**	**53,000**
Total, Nuclear Physics	**690,000**	**713,000**

Enacted Appropriation: $713,000,000 for NP. Directs $28,500,000 for FRIB operations. Also directs optimal funding for operations, major items of equipment, and other project costs. $1,000,000 provided for the first year of EIC TEC funds, $12,000,000 for the first year of US SIPRC TEC funds, and $40,000,000 for FRIB Construction funds.

NP - FY 2020 Highlights

Nuclear Physics *(NP: FY 2019 $690M; FY 2020 $713M)*

- Continued support of critical nuclear physics research and operations
  - FY 2020 supports highest priority research in all scientific thrusts.
  - FY 2020 features NP FOAs for exciting new science in QIS, advances in Interagency Nuclear Data efforts, Isotope Production R&D and Accelerator R&D.
  - Research on Isotope production and separation enables viability of new life saving cancer treatments and enhancement of stable isotope production to mitigate U.S. dependence on foreign supply. Increased QIS funding develops production capabilities for isotopes of interest to next generation QIS systems.
  - RHIC, CEBAF, and ATLAS facilities on the average operate at >90% operations in FY 2020, and FRIB, which is more than 93% complete, is supported at Cooperative Agreement levels in preparation of construction completion in FY 2022.

NP - FY 2020 Highlights (cont...)

- The first year of OPC and TEC funding for the Electron Ion Collider, which received CD-0 in Q1 FY 2020 and a site selection at BNL in Q2 FY2020, enabling research and development, conceptual design, and early engineering designs for this revolutionary, next-generation NP facility.
- The first year of funding for the U.S. SIPRC construction effort supports project engineering design efforts and long lead procurements that initiates a future of U.S. stable isotope independence.
- The High Rigidity Spectrometer at FRIB, MOLLER, and Ton-Scale Neutrinoless Double Beta Decay MIEs receive TEC starts. GRETA and sPHENIX MIEs continue to be supported. The SIPF MIE receives last year of TEC funding.
- The FRIB Isotope Harvesting accelerator project is initiated to exploit the unique capabilities of FRIB

The FY2020 Appropriation occasions both exciting new prospects and significant challenges. One of the challenges is that once directed steps are taken (facility ops, new starts, construction), the remaining budget for research is reduced by ≈ 5.5% . The Research Division Program Managers have worked diligently to mitigate the most negative immediate impacts of this reduction for FY 2020.

FY 2021 SC President's Budget Request

(Dollars in Thousands)

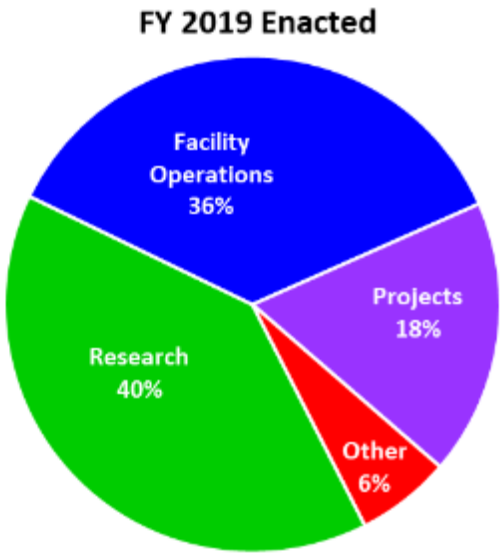
	FY 2019		FY 2020	FY 2021 President's Request		
	Enacted Approp.	Current Approp.	Enacted Approp.	President's Request	President's Request vs. FY 2020 Enacted	
Office of Science						
Advanced Scientific Computing Research	935,500	910,031	980,000	988,051	+8,051	+0.8%
Basic Energy Sciences	2,166,000	2,105,873	2,213,000	1,935,673	-277,327	-12.5%
Biological and Environmental Research	705,000	680,246	750,000	516,934	-233,066	-31.1%
Fusion Energy Sciences	564,000	549,181	671,000	425,151	-245,849	-36.6%
High Energy Physics	980,000	955,905	1,045,000	818,131	-226,869	-21.7%
Nuclear Physics	690,000	669,888	713,000	653,327	-59,673	-8.4%
Workforce Development for Teachers and Scientists	22,500	22,500	28,000	20,500	-7,500	-26.8%
Science Laboratories Infrastructure	232,890	232,890	301,000	174,110	-126,890	-42.2%
Safeguards and Security	106,110	106,110	112,700	115,623	+2,923	+2.6%
Program Direction	183,000	183,000	186,300	190,306	+4,006	+2.2%
SBIR/STTR (SC)		169,376	...	...	...	...
Total Budget Authority and Obligations, Office of Science	**6,585,000**	**6,585,000**	**7,000,000**	**5,837,806**	**-1,162,194**	**-16.6%**
SBIR/STTR (DOE)	...	123,254	...	...	...	...
Total, Office of Science	**6,585,000**	**6,708,254**	**7,000,000**	**5,837,806**	**-1,162,194**	**-16.6%**

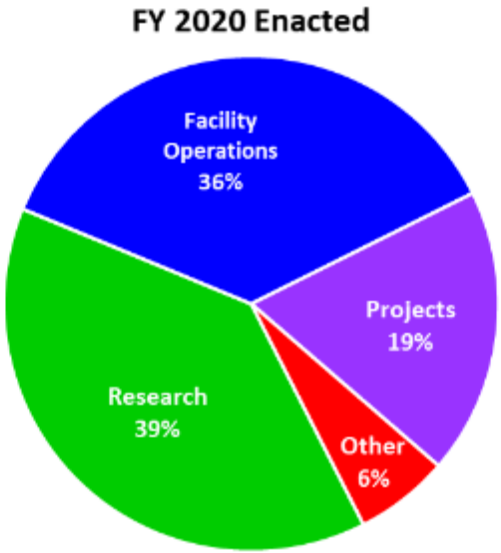
FY 2021 SC President's Request by Budget Element

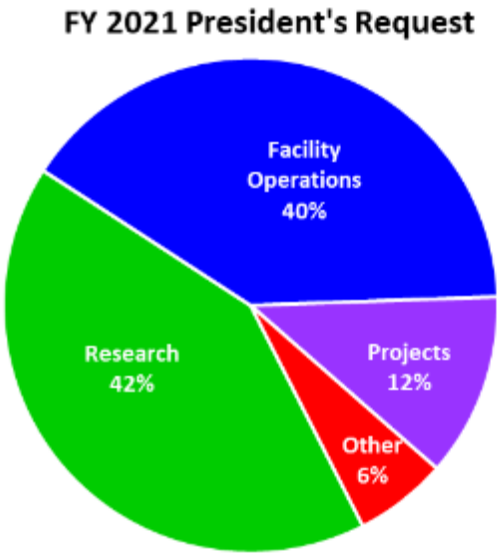
(Dollars in Thousands)

	FY 2019		FY 2020		FY 2021 Request					
	Enacted	% of Total	Enacted	% of Total	President's Request	% of Total	vs. FY 19 Enacted		vs. 20 Enacted	
							$ Change	% Change	$ Change	% Change
Research	2,613,181	39.7%	2,713,198	38.8%	2,432,427	41.7%	-180,754	-6.9%	-280,771	-10.3%
Facility Operations	2,381,466	36.2%	2,545,988	36.4%	2,351,500	40.3%	-29,966	-1.3%	-194,488	-7.6%
Projects	1,184,296	18.0%	1,309,214	18.7%	699,940	12.0%	-484,356	-40.9%	-609,274	-46.5%
Other	406,057	6.2%	431,600	6.2%	353,939	6.1%	-52,118	-12.8%	-77,661	-18.0%
Total	**6,585,000**	**100.0%**	**7,000,000**	**100.0%**	**5,837,806**	**100.0%**	**-747,194**	**-11.3%**	**-1,162,194**	**-16.6%**

*Other includes GPP/GPE, WDTS, S&S, and PD.







Nuclear Physics in FY21

Discovering, exploring, and understanding all forms of nuclear matter

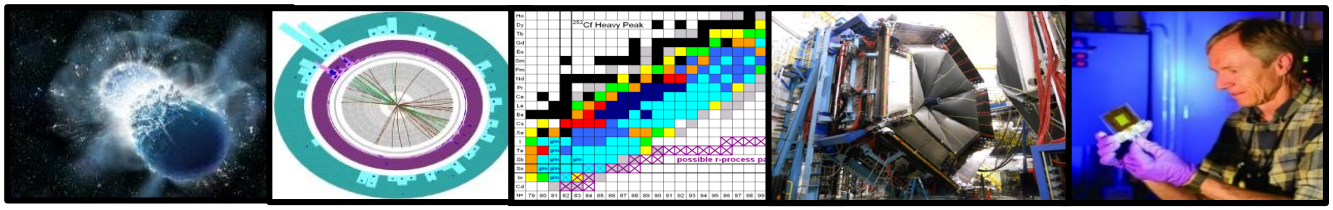
- Funding for research at national labs and universities is focused on the highest priority research in relativistic nuclear collisions, hadron physics, nuclear structure and nuclear astrophysics, and fundamental symmetries. NP increases its participation in planned coordinated SC **Quantum Information Science (QIS)** research and facility activities and begins its involvement in **Artificial Intelligence/Machine Learning (AI/ML)** and the **SC Strategic Accelerator R&D initiative**.

- **RHIC** operates at ~100% of maximum available runtime to explore the properties of the quark gluon plasma first discovered there. The recently upgraded **12 GeV CEBAF** operates at ~68% optimal, promising new discoveries and an improved understanding of quark confinement. Operations at **ATLAS** are supported at ~44% 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** continues in advance of construction completion.

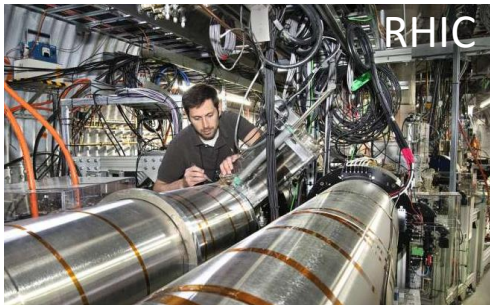
- The **Facility for Rare Isotope Beams** receives its final year of construction funding**. The Gamma-Ray Energy Tracking Array (GRETA)** MIE is continued to extend FRIB's reach in studying the nuclear landscape**.** The **sPHENIX MIE** continues within current RHIC funding levels for precision, high rate particle jet studies. The **Moller MIE** continues for ultra-precise measurements with the upgraded CEBAF machine. The **Ton-Scale Neutrinoless Double Beta Decay MIE** continues 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. While all required funding had been previously provided, work continues of the **Stable Isotope Production Facility (SIPF)** MIE to produce kilogram quantities of enriched stable isotopes.

- Conceptual design efforts and R&D (OPC) and project engineering efforts (TEC) are supported for the **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 and which received CD-0 in December 2019.

- 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 continues in order to significantly increase production capabilities for stable isotopes and eliminate sole dependence on foreign supply.

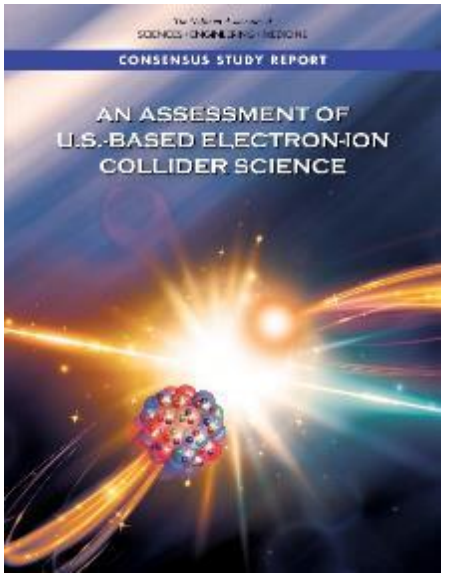


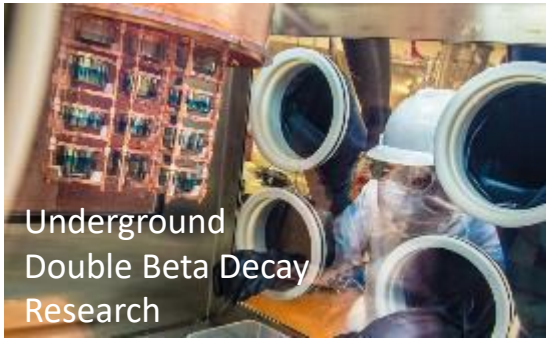
NP - FY 2021 Highlights



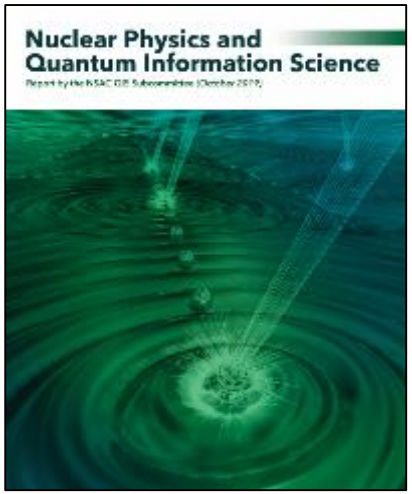
World leading research supported at state-of-the-art NP National User Facilities

The vision to maintain U.S. leadership and eliminate foreign dependence on isotopes continues to be implemented:
EIC construction;
SIPRC construction;
FRIB construction





Pioneering experiments and research tools (MIEs) are created



Groundbreaking contributions to national cross-cutting priorities continue

NP FY 2021 President's Request

(Dollars in thousands)

Office of Nuclear Physics	FY 2019	FY 2020	FY 2021 President's Request		
	Enacted	Enacted	President's Request	President's Request vs. FY 2020 Enacted	
Medium Energy Nuclear Physics					
Research	43,508	41,454	35,500	-5,954	-14.4%
Operations	118,440	123,610	118,000	-5,610	-4.5%
Other Research	2,934	3,467	2,800	-667	-19.2%
SBIR/STTR	20,112	20,858	19,438	-1,420	-6.8%
Total, Medium Energy Nuclear Physics	**184,994**	**189,389**	**175,738**	**-13,651**	**-7.2%**
Heavy Ion Nuclear Physics					
Research	35,854	37,211	31,508	-5,703	-15.3%
Operations	191,771	195,151	194,928	-223	-0.1%
Total, Heavy Ion Nuclear Physics	**227,625**	**232,362**	**226,436**	**-5,926**	**-2.6%**
Low Energy Nuclear Physics					
Research	70,565	70,698	60,636	-10,062	-14.2%
Operations	31,331	56,039	50,241	-5,798	-10.3%
Total, Low Energy Nuclear Physics	**101,896**	**126,737**	**110,877**	**-15,860**	**-12.5%**
Nuclear Theory					
Theory Research	47,345	43,062	46,750	+3,688	+8.6%
Nuclear Data	8,881	8,950	7,726	-1,224	-13.7%
EIC OPC Funding	-	10,000	1,500	-8,500	-85.%
Tota, Nuclear Theory	**56,226**	**62,012**	**55,976**	**-6,036**	**-9.7%**
Isotope Development and Production for Research Applications					
Research	9,808	11,500	22,000	+10,500	+91.3%
Operations	34,451	38,000	44,000	+6,000	+15.8%
Total, Isotope Production and Applications	**44,259**	**49,500**	**66,000**	**+16,500**	**+33.3%**
Subtotal, NP	**615,000**	**660,000**	**635,027**	**-24,973**	**-3.8%**
Construction					
14-SC-50 Facility for Rare Isotope Beams	75,000	40,000	5,300	-34,700	-86.8%
20-SC-51, U.S. Stable Isotope Production and Research Center	-	12,000	12,000	-	-
21-SC-52, Electron Ion Collider	-	1,000	1,000	-	-
Total, Construction	**75,000**	**53,000**	**18,300**	**-34,700**	**-65.5%**
Total, Nuclear Physics	**690,000**	**713,000**	**653,327**	**-59,673**	**-8.4%**

Summary of 2021 Changes Relative to FY 2020

FY 2020 Enacted	FY 2021 President's Request
Core Research reduced 5.5% from FY19 Enacted (including COL, this is an 8.3% cut from constant effort in FY19). New ECA awards are made.	**Core research** reduced 10.6% from FY20 Enacted. (including COL, this is a 13.2% cut from FY20 constant effort and a 20.4% cut from FY19 constant effort.) This reduction also includes the elimination of new ECA awards in FY21.
LHC M&O commitments met.	**LHC M&O** commitments delayed until FY 2022.
FRIB Research supported as planned.	**FRIB Research** ramping is slowed down relative to plans.
nEDM supported modestly below planned profile.	**nEDM** supported significantly below planned profile, possibly impacting schedule.
SciDAC maintained relative to FY 2019	**SciDAC** maintained relative to FY 2020
Nuclear Data held flat with FY19 Enacted	**Nuclear Data** decreased 12.2% from FY20 Enacted
QIS at $10.3M (a $2M increase in IP QIS, NP QIS flat)	**QIS** at $13M (NP QIS increases 2.7M, IP QIS is flat)
Accelerator R&D is increased	**Accelerator R&D** is cut 15.5% from FY19 enacted levels
	New Accelerator Strategic Initiative (+1M)
-	**New ML/AI Initiative** ($4M)

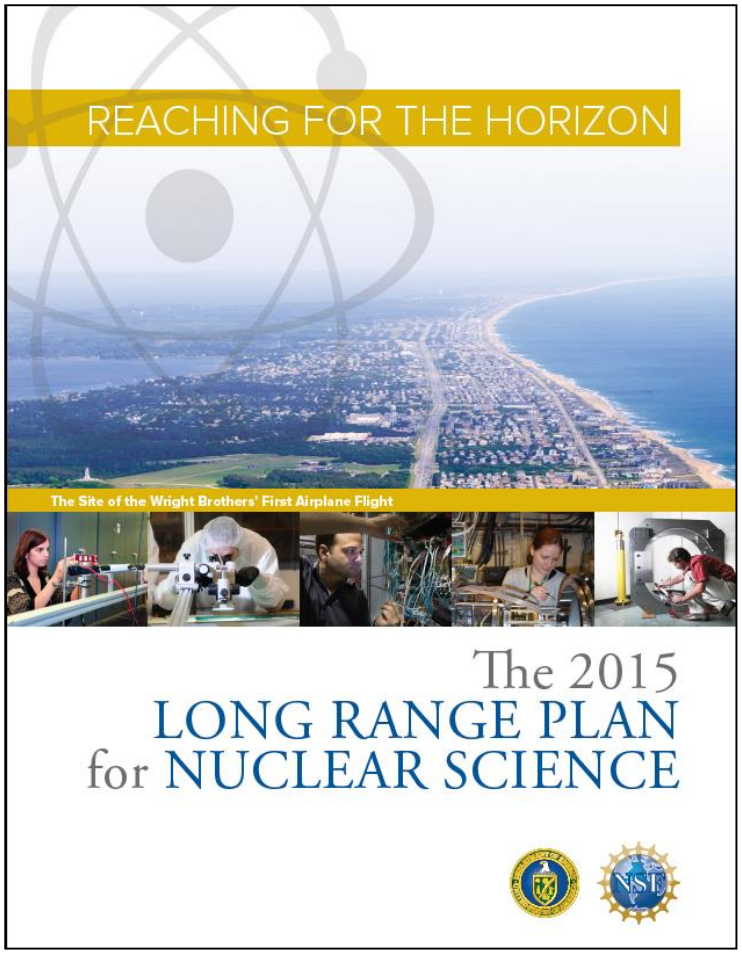
Summary of 2021 Changes Relative to FY 2020

FY 2020 Enacted	FY 2021 President's Request
Facility operations at constant effort - **RHIC** operates 28 weeks (100 % optimal) - **CEBAF** operates 22.5 weeks (100 % maximum) - **ATLAS** operates 41 weeks (90 % optimal)	**Facilities operations** at constant effort - **RHIC** operates 24 weeks (100 % maximum) - **CEBAF** operates 23 weeks (68 % optimal) - **ATLAS** operates 20 weeks (44 % optimal)
FRIB operations supported at planned level $28.5M	**FRIB ops** supported below planned levels ($25.6 vs 59.8M)
FRIB construction at baselined $40M	**FRIB construction** at baselined $5.3M
EIC construction at TEC of $1M and OPC of $10M	**EIC construction** at TEC of $1M and OPC of $1.5M
Ongoing Major Item of Equipment: - **GRETA** reduced below planned levels ($6.6M) - **sPHENIX** at planned baseline level ($9.52M) - **SIPF** at planned baseline level ($1.5M)	**Ongoing Major Item of Equipment:** - **GRETA** below planned levels ($2.5M) - **sPHENIX** below baseline level ($3M)
New Major Items of Equipment initiated - **MOLLER** at $2M TEC - **TSNLDBD** at $1M TEC - **HRS** at $1M TEC	**Major Items of Equipment initiated in FY 2020** - **MOLLER** reduced to $300k TEC - **TSNLDBD** at $1.44M TEC - **HRS** at $1M TEC
Isotope Research increases by 17.3 % relative to FY 19	**Isotope Research** increases 91% ($10.5M) over FY20 Enacted
Isotope Operations increases $10.3 %, including $2.1M **SIPRC OPC.**	**Isotope Operations** increased 16% ($6M)
SIPRC construction at $12M	**SIPRC construction** at $12M

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 FY2021 Request allows NP to continue to pursue aspects of the 2015 LRP Vision

General Outlook

- The experience with FY18, FY19 and FY20 budgets has required readiness for big swings in the budget. FY2021 is 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!

Facility for Rare Isotope Beams is > 93% Complete

FRIB will increase the number of isotopes with known properties from ~2,000 observed over the last century to ~5,000 and will provide world-leading capabilities for research on:

Nuclear Structure

- The limits of existence for nuclei
- Nuclei that have neutron skins
- Synthesis of super heavy elements

Nuclear Astrophysics

- The origin of the heavy elements and explosive nucleo-synthesis
- Composition of neutron star crusts

Fundamental Symmetries

- Tests of fundamental symmetries, Atomic EDMs, Weak Charge

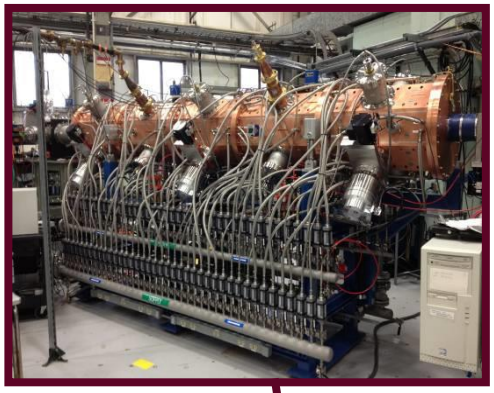
This research will provide the basis for a predictive model of nuclei and how they interact.

The FY 2021 Request supports:

- Completed fabrication and assembly of the linear accelerator (linac) cryomodule, allowing continued installation and testing in the constructed tunnel.
- Fabrication, assembly, installation and testing of the experimental systems, and the commissioning of the linac and other components.

	PYs	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	DOE Total	MSU	TOTAL
FUNDING PROFILE	318,000	100,000	97,200	75,000	40,000	5,300	635,500	94,500	730,000

ATLAS Continues as a Premier Stable Beam Facility



ATLAS is a unique premier Stable Beam Facility for research on Nuclear Structure & Nuclear Astrophysics

Multi-User Upgrade AIP Planned

ATLAS operates at ~44% optimal in FY21

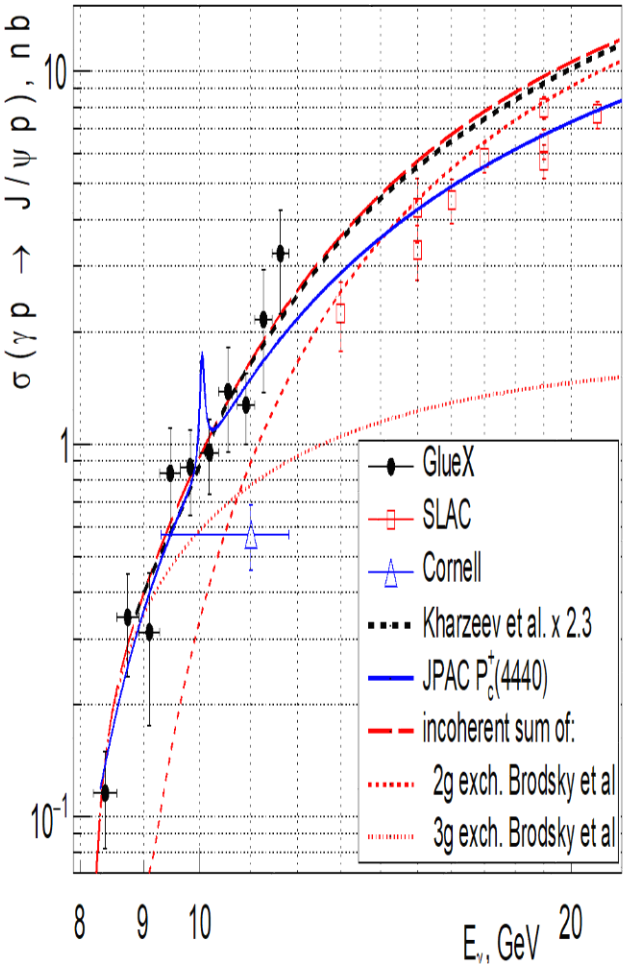
12 GeV CEBAF Science Program is Underway

CEBAF operates at ~68% optimal in FY21

New results from GlueX illuminate the mechanism of threshold J/Psi production and the upper limit on the pentaquark. The latter provides constraints on the structure of the LHCb pentaquark, favoring a molecular description.

Phys. Rev. Lett. 123, 072001(2019)

$$\gamma p \rightarrow pJ/\psi \rightarrow pe^+e^-$$

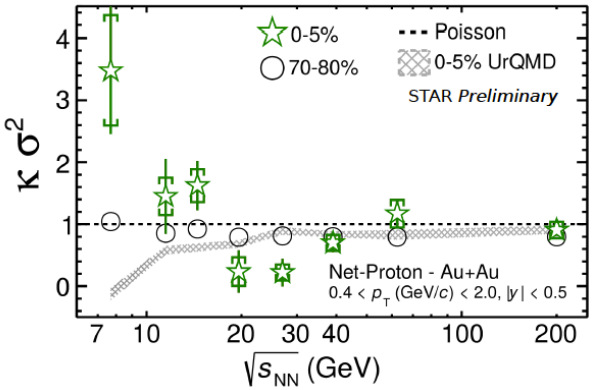


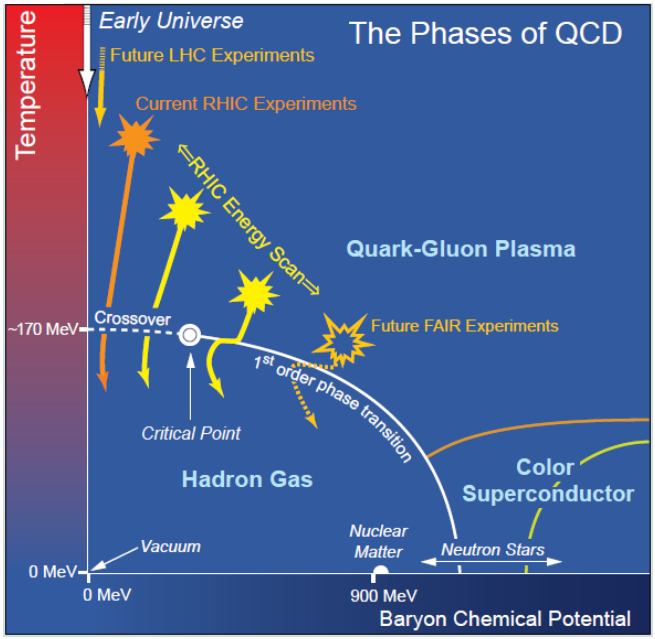
(Based on ~25% of collected data.)

For Beam Energy Scan II (BESII) Statistics One of the Challenges

RHIC operates 24 weeks for data taking in FY21

One striking fact is that the liquid-vapor curve can end. Beyond this "Critical Point" the sharp distinction between liquid and vapor is lost. Experimentally verifying the location of fundamental QCD "landmarks" such as the Critical Point is central to a quantitative understanding of the nuclear matter phase diagram.





A primary signature of the Critical Point: non-Poissonian scaled kurtosis (net baryon number fluctuations)

- RHIC has Consistently high facility availability (~85%)
- No other facility worldwide, existing or planned, rivals RHIC in science reach and versatility as a heavy ion collider. It is the only polarized proton collider in the world.

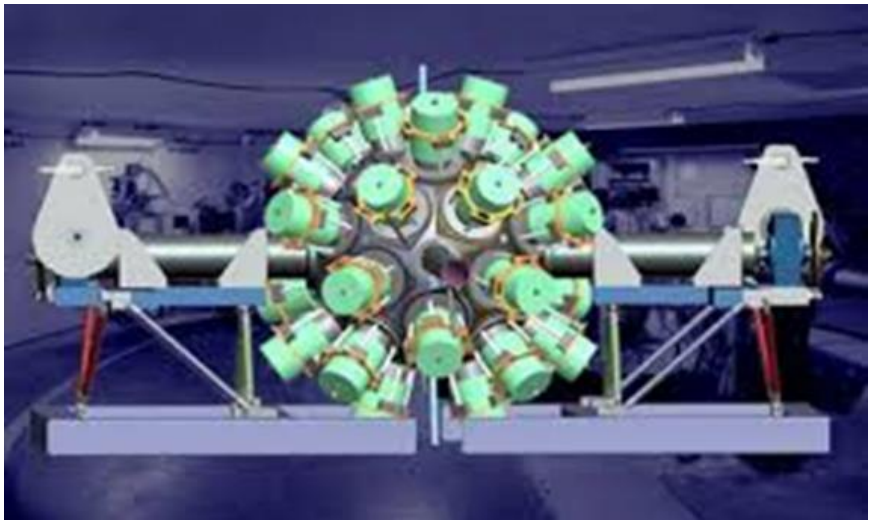
All ongoing MIEs continue in the FY2021 Request

Construction of GRETA and Progress on HRS for FRIB Continue

- The Gamma Ray Energy Tracking Array (GRETA) will advance the rare-isotope science at FRIB and investigate reactions of importance for nuclear structure and nuclear astrophysics.
- Est. Total Project Cost: $52M-$65M

FY 2020 Enacted: $6.6M

FY 2021 Request: $2.5M

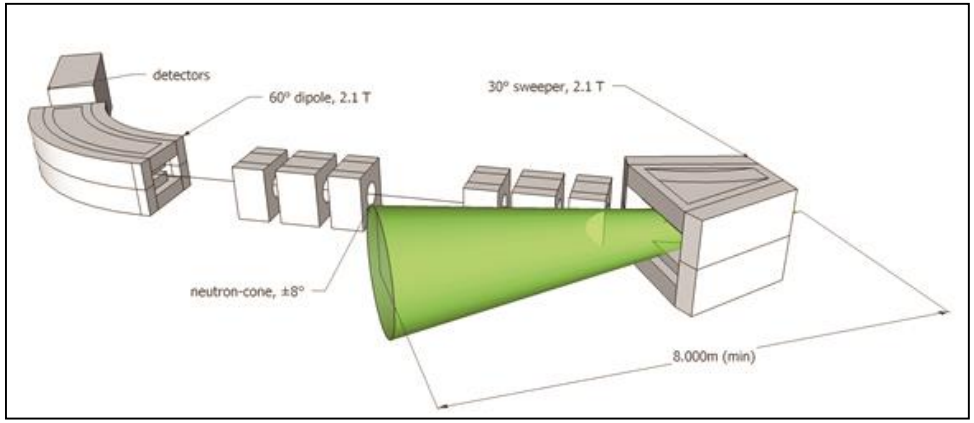


GRETA Array

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.

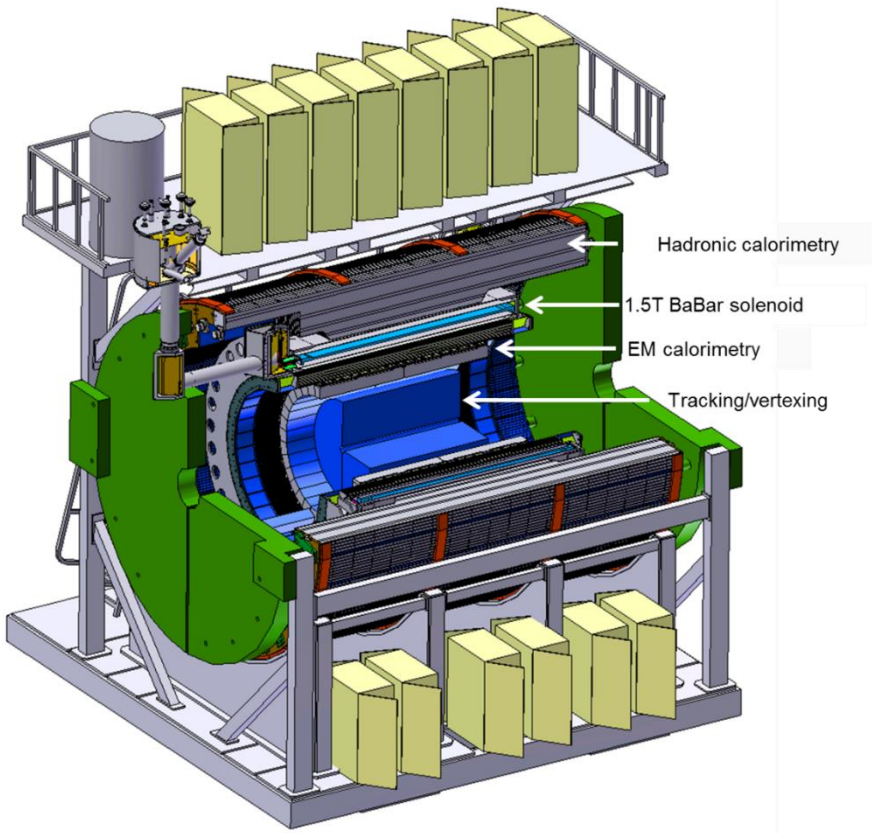
FY 2020 Enacted: $1M

FY 2021 Request: $1M



High Rigidity Spectrometer (HRS) Concept

Within Available Funds, the sPHENIX Upgrade is Continued



FY2020 Enacted: $9.524M

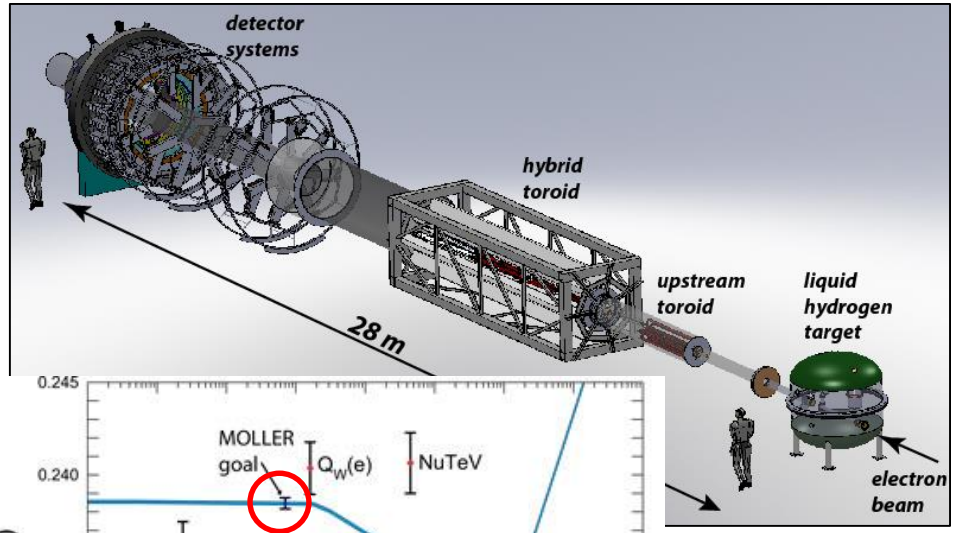
FY2021 Request: $3M

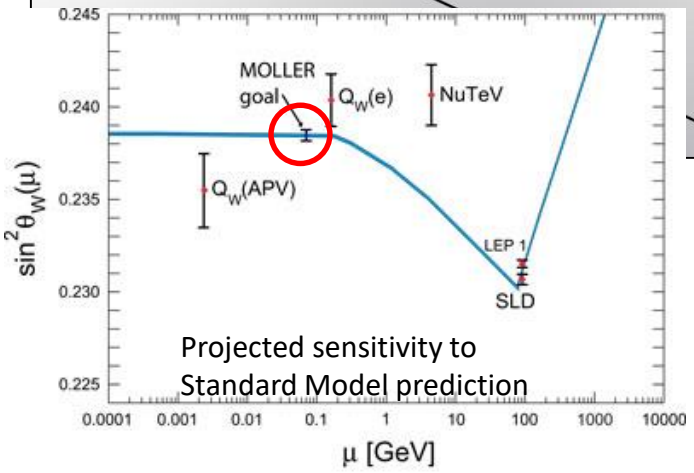
- mapping the character of the hadronic matter under extreme conditions by varying the temperature of the medium, the virtuality of the probe, and the length scale within the medium.
- understanding the parton–medium interactions by studying heavy-flavor jets.
- probing the effect of the quark–gluon 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.

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.

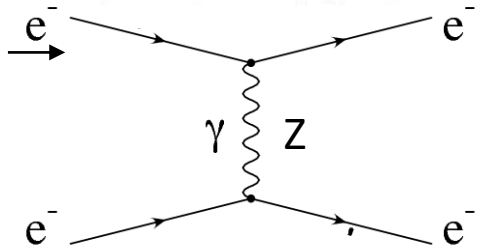




Projected sensitivity to Standard Model prediction

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 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.

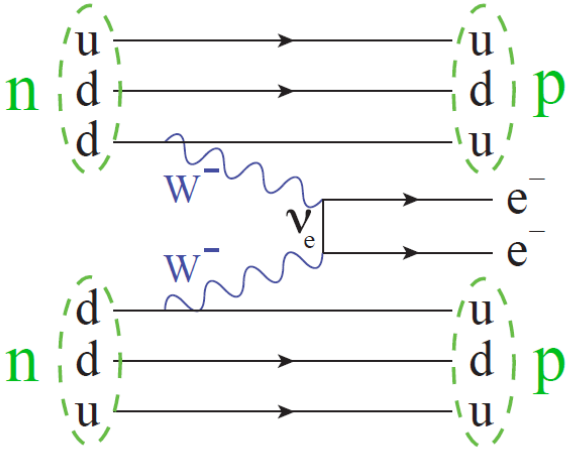
FY 2020 Enacted: $2M

FY 2021 Request: $300k

The Campaign to Determine the Fundamental Nature of the Neutrino

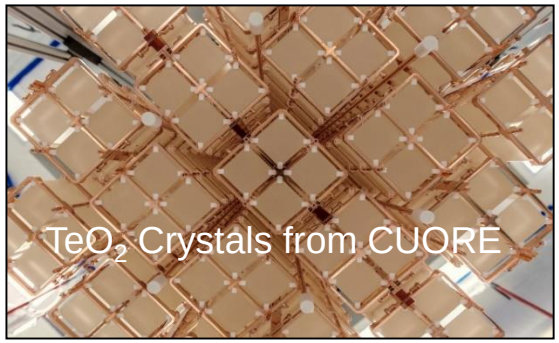
How can it be determined whether the neutrino is a Majorana Particle?

Search for Neutrino-less Double Beta Decay ($0\nu\beta\beta$): 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

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

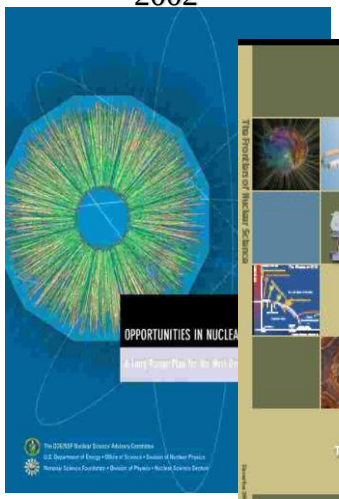
FY 2020 Enacted: $1M

FY 2021 Request: $1.44M

The Science Case for An Electron-Ion Collider

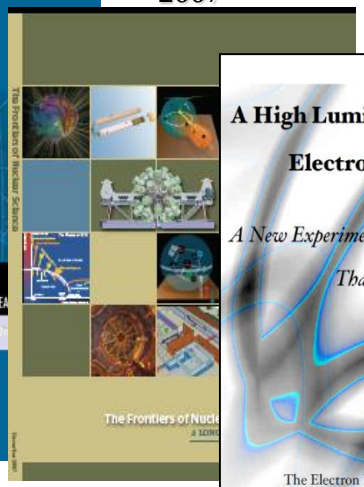
A strong community emphasis on the urgent need for a machine to illuminate the dynamical basis of hadron structure in terms of the fundamental quark and gluon fields has been a persistent message for almost two decades

2002



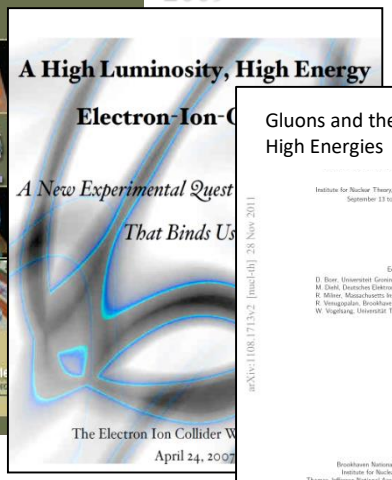
"…essential accelerator and detector R&D [for EIC] should be given very high priority in the short term."

2007



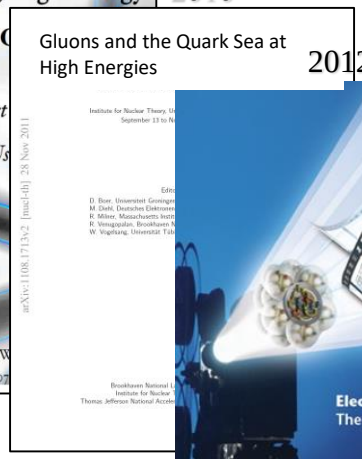
"We recommend the allocation of resources …to lay the foundation for a polarized Electron-Ion Collider…"

2009

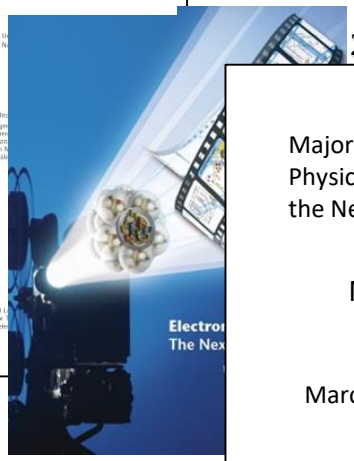


"..a new dedicated facility will be essential for answering some of the most central questions."

2010



2012



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

2013

Major Nuclear Physics Facilities for the Next Decade

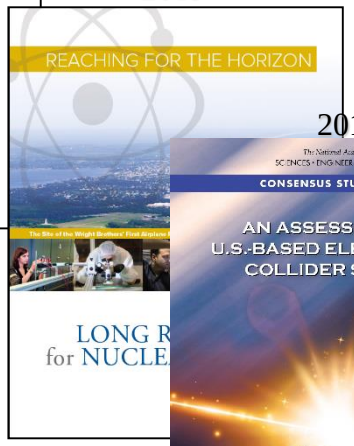
NSAC

March 14, 2013

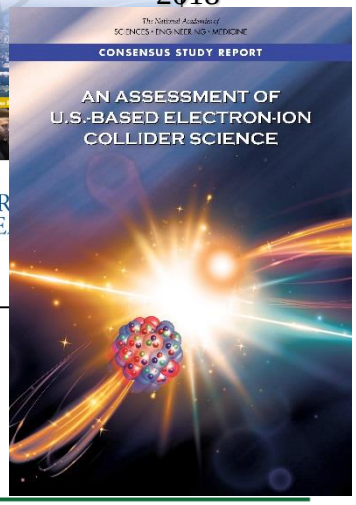
Electron-Ion Collider..*absolutely central* to the nuclear science program of the next decade.

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

2015



2018



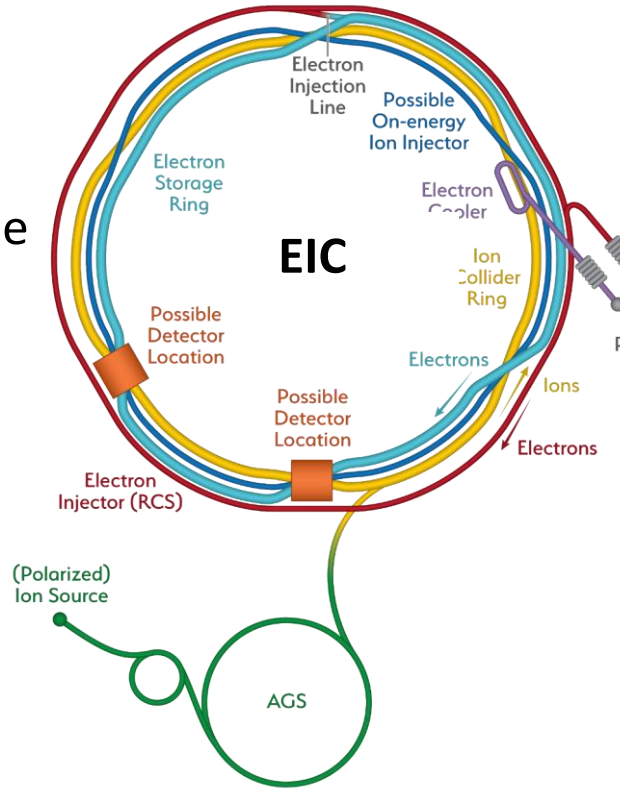
Important Milestones for the EIC

- Mission Need Statement Approved: January 22, 2019
  - Total Project Cost (TPC) range: $1.1 - $2.5 Billion
- Independent Cost Review (ICR) as required by DOE Order 413.3b completed July 31, 2019
- Independent Electron Ion Collider Site Assessment: October 8-9th
- FY 2020 Enacted Budget includes both TEC and OPC for EIC
- CD-0 was approved by DOE in December 2019
- Site Selection at Brookhaven National Laboratory was announced by DOE in January 2020

EIC Receives CD0 and Will be Sited at BNL

An SC Prime Directive: The Project will be carried out as a full intellectual partnership between the BNL and JLAB teams (and other collaborators) with major participation by all

- TPC range of EIC is $1.6B – $2.6B; complete early next decade
- TPC and completion of project dependent upon congressional appropriation and final agreed upon scope when baselined
- Magnitude of reprioritized funds ranges from ~$0.6B – $1.2B over the lifetime of the project.
- Reprioritization of activities towards the EIC also decreases the amount of new funding required
- The EIC could be implemented with caps on amount of new funds needed on an annual basis and still be implemented successfully and in a timely manner. l



Office of Science FY 2021 Continuing Research Initiatives

- Machine Learning/Artificial Intelligence
- Bio (security, materials, manufacturing)
- Quantum Information Science - includes quantum sensing, computing, networking, and isotope production
- Exascale Computing
- Microelectronics Innovation
- National Isotopes Strategy
- U.S. Fusion Program Acceleration

Office of Science FY 2021 New Research Initiatives

- **Integrated Computational and Data Infrastructure for Scientific Discovery**: Design and deploy a flexible multi-tiers data and computational management architecture that enables a diverse array of on-demand scientific workflows and simulations for SC mission research.
- **Next Generation Biology Initiative**: Support research in areas of neuromorphic computing, programmable biomaterials and biocatalysts, and next-generation tools for characterization of biological, biomaterials, and biohybrid systems.
- **Rare Earth/Separation Science Initiative**: Understanding the fundamentals of rare earth properties; enhancing separations and chemical processing for rare earths.
- **Revolutionizing Polymer Upcycling**: Elucidating the chemical and biological pathways for transforming polymers and synthesizing high-value chemicals or new polymers.
- **Strategic Accelerator Technology Initiative**: Support investments in accelerator technologies, advanced magnet Revolutionary Light Sources.
- **Data and Computational Collaboration with NIH**: Support DOE laboratories in partnership with NIH to expand the capabilities of DOE's tools and address NIH's rapidly growing data and computational challenges.

Office of Science - FY 2021 Research Initiatives

Dollars in Thousands

Dollars in Thousands

Initiative Name	FY 2019 Enacted	FY 2020 Enacted	FY 2021 President's Request	ASCR	BES	BER	FES	HEP	NP	Total
New Initiatives										
Integrated Computational and Data Infrastructure for Scientific Discovery	-	-	11,845	11,845						11,845
Next Generation Biology Initiative	-	-	10,000		3,750	6,250				10,000
Rare Earth / Separation Science Initiative	-	-	25,000		25,000					25,000
Revolutionizing Polymer Upcycling	-	-	14,500		8,250	6,250				14,500
Strategic Accelerator Technology Initiative	-	-	13,500		6,250		-	6,250	1,000	13,500
Data and Computational Collaboration with NIH			1,000	1,000						1,000
Ongoing Research Initiatives										
Artificial Intelligence and Machine Learning	21,964	71,000	124,500	56,000	20,000	3,000	7,000	34,500	4,000	124,500
Biosecurity	4,000	20,000	25,000			25,000				25,000
DOE Isotope Initiative	-	3,241	16,500						16,500	16,500
Exascale Computing Initiative	513,706	504,735	474,945	438,945	26,000	10,000				474,945
Microelectronics	4,800	5,000	45,000	5,000	30,000		5,000	5,000		45,000
Quantum Information Science	123,483	195,270	236,761	86,162	72,270	12,000	9,520	43,809	13,000	236,761
U.S. Fusion Program Acceleration	2,000	4,000	5,000				5,000			5,000
Total	669,953	803,246	1,003,551	598,952	191,520	62,500	26,520	89,559	34,500	1,003,551

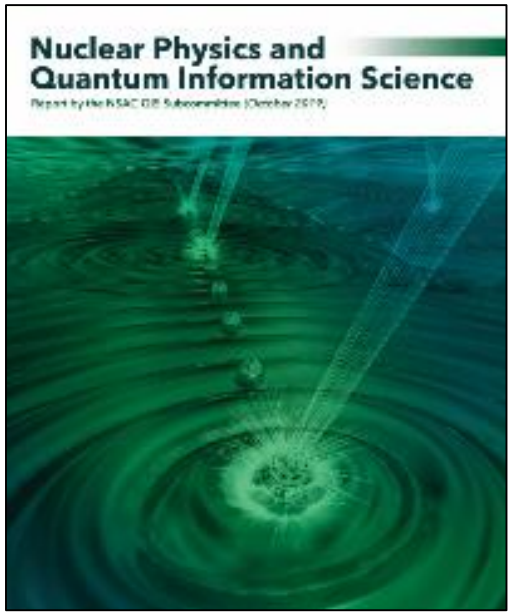
FY 2019 NP QIS/QC Activities

Activity	Funding
Or Hen (MIT) ECA – "Study of Short-Range Correlations in Nuclei Using Electro-induced Nucleon-knockout Reactions at High Momentum-Transfer"	$750,000
Jiehang Zhang (NYU) ECA – "Exploring Quantum Many-body Physics with a Trapped Ion Quantum Information Processor"	$750,000
Zohreh Davoudi (UMD) ECA – "Analog and Digital Quantum Simulations of Strongly Interacting Theories for Applications in Nuclear Physics"	$750,000
TJNAF QIS Mini-Lecture Series on Quantum Computing and Quantum Information Science for Nuclear Physics.	$50,000
Uconn Workshop on NP and QIS	$24,000

$6.726M of FY 2019 QIS funding carried over into FY2020 for awards tied to the FY2019 QIS FOA.

NSAC Assessment of the QIS Role of Nuclear Science is Complete

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].



Peer review process for proposals received in respond to NP FY2019 FOA is continuing

SC peer review process for proposals received in response to FOA on establishing QIS Centers is in progress

An FY2020 NP QIS FOA is Anticipated

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

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

In the long-term have a transformative impact on NP mission area and/or advance QIS development enabled by NP-supported science, technologies, and laboratory infrastructure….

Plan is to Conduct Peer Review and Make Awards in FY2021

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
- Cuts across many DOE programs
  - OE, EE, FE, NE, NNSA
- Cuts across multiple U.S. Government Agencies, including NIH and DoD
- FY 2020 SC request - $71M
  - patterned after the Exascale Computing Project

A cross-cutting FOA lab call is anticipated in FY2020

A New Inter-Agency FOA on Nuclear Data is Anticipated

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**

A New FOA on Accelerator R&D is Anticipated

DEPARTMENT OF ENERGY
OFFICE OF SCIENCE, NUCLEAR PHYSICS
OFFICE OF SCIENCE, NUCLEAR PHYSICS, ISOTOPES PROGRAM

FINANCIAL ASSISTANCE FUNDING OPPORTUNITY ANNOUNCEMENT

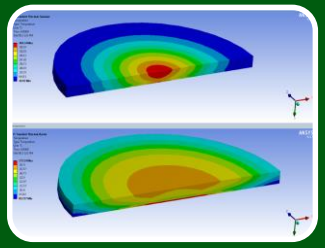
U. S. Department of Energy Office of Science Nuclear Physics

FY 20XX Topic: Research and Development for Next Generation Nuclear Physics Accelerator Facilities

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

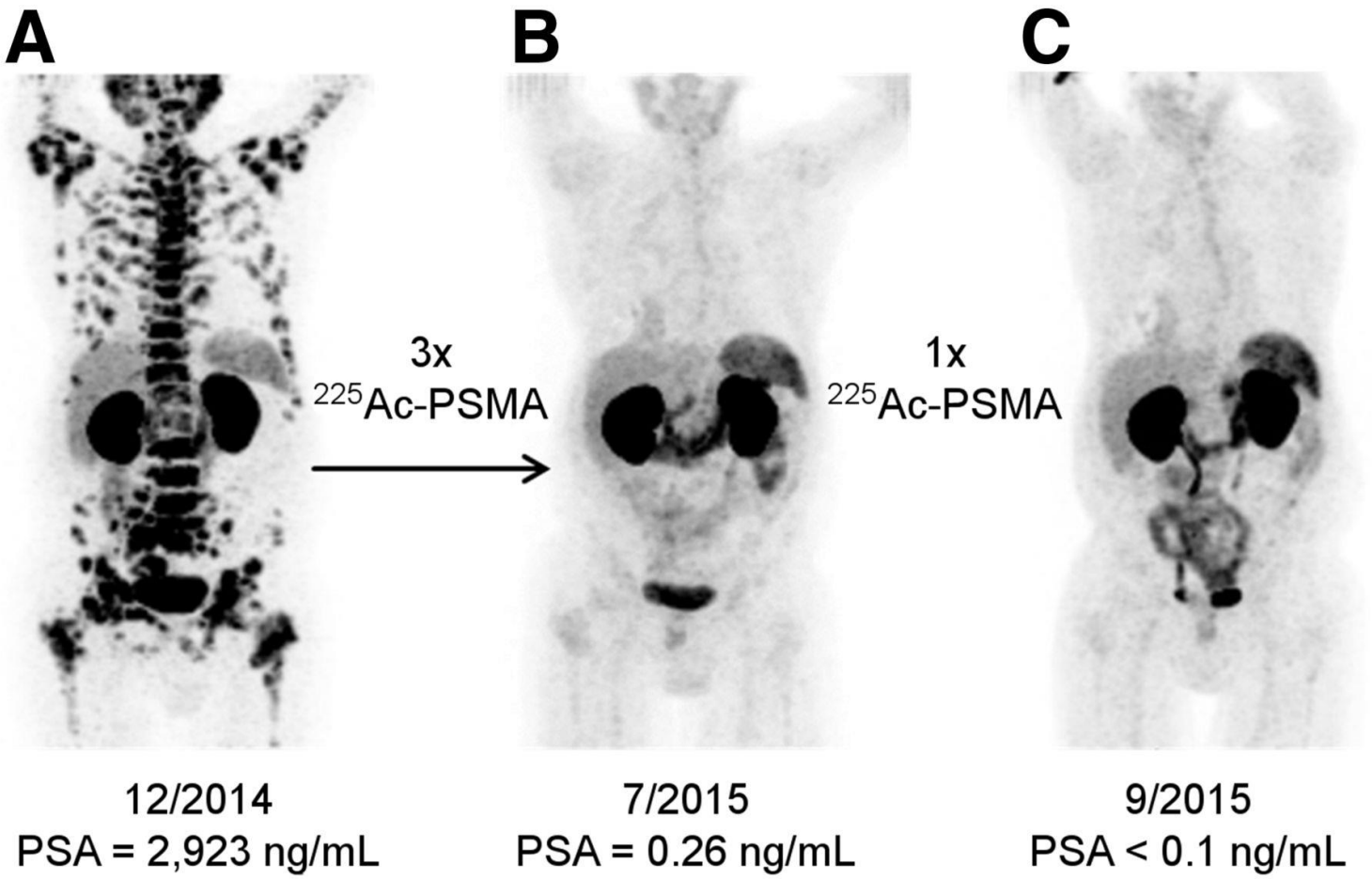
Maintain the infrastructure required to produce and supply priority isotope products and related service



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

Support for Isotope Research/Mission Readiness is Enabling the Saving of Lives



Ga-68 PET/CT scans of a different patient with metastatic prostate cancer. Image **A** shows pre-therapeutic tumor spread. Image **B** was taken 2 months after the third cycle of treatment with the α-emitting isotope Ac-225 attached to a tumor seeking drug. Image **C** was taken 2 months after one additional treatment dose. Clemens Kratochwil et al. J Nucl Med 2016;57:1941-1944

Stable Isotope Production Facility (SIPF) and SIPRC

- FY 2020 was 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 US SIPRC at ORNL.

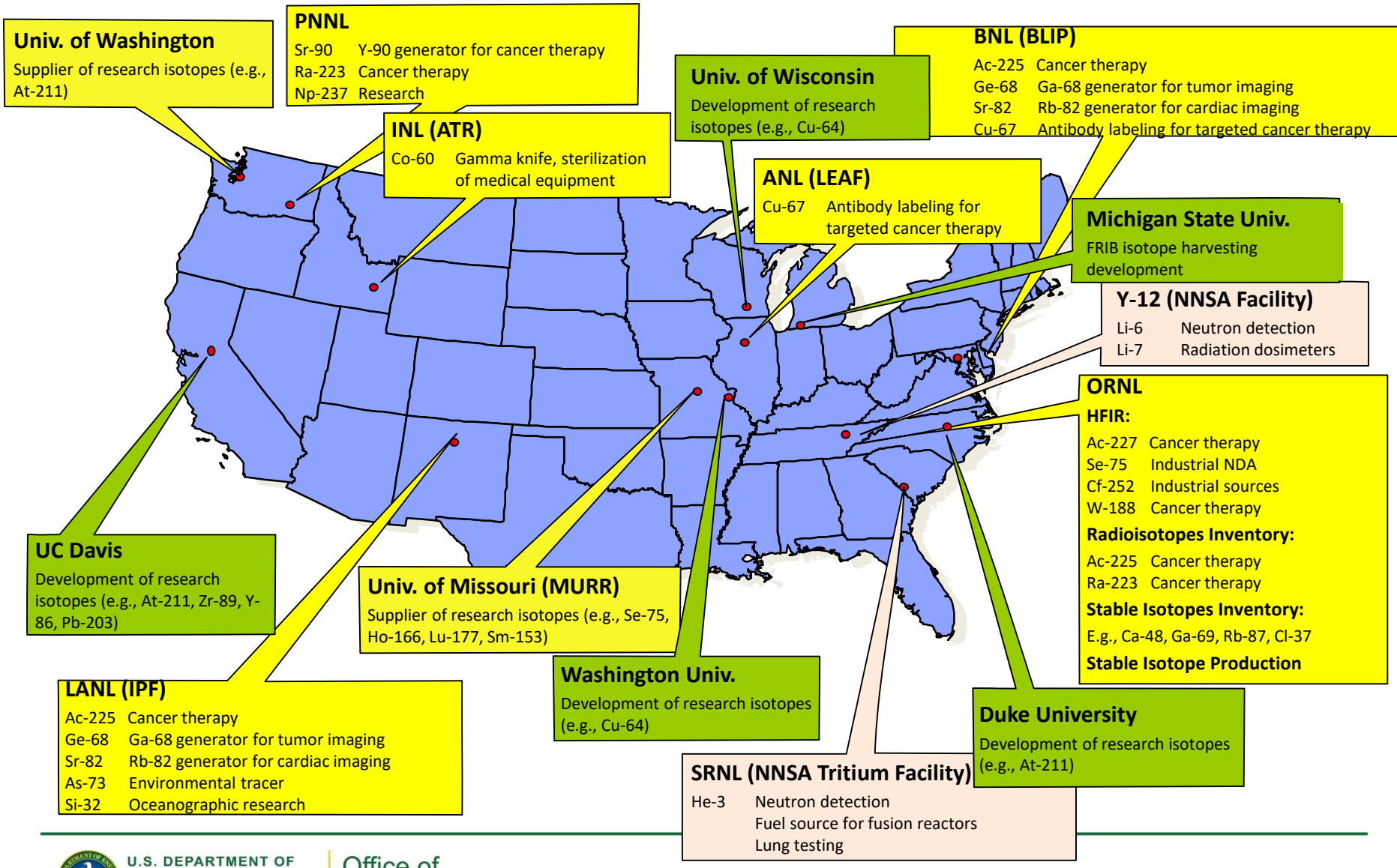
FY2020 Enacted: $12M of TEC, $2.1M of OPC

FY2021 Request: $12M of TEC

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.”

DOE Isotope Program Production and/or Development Sites -2018



FRIB Isotope Harvesting

FRIB will create Ci-quantities of useful radioisotopes as byproducts of normal operations.

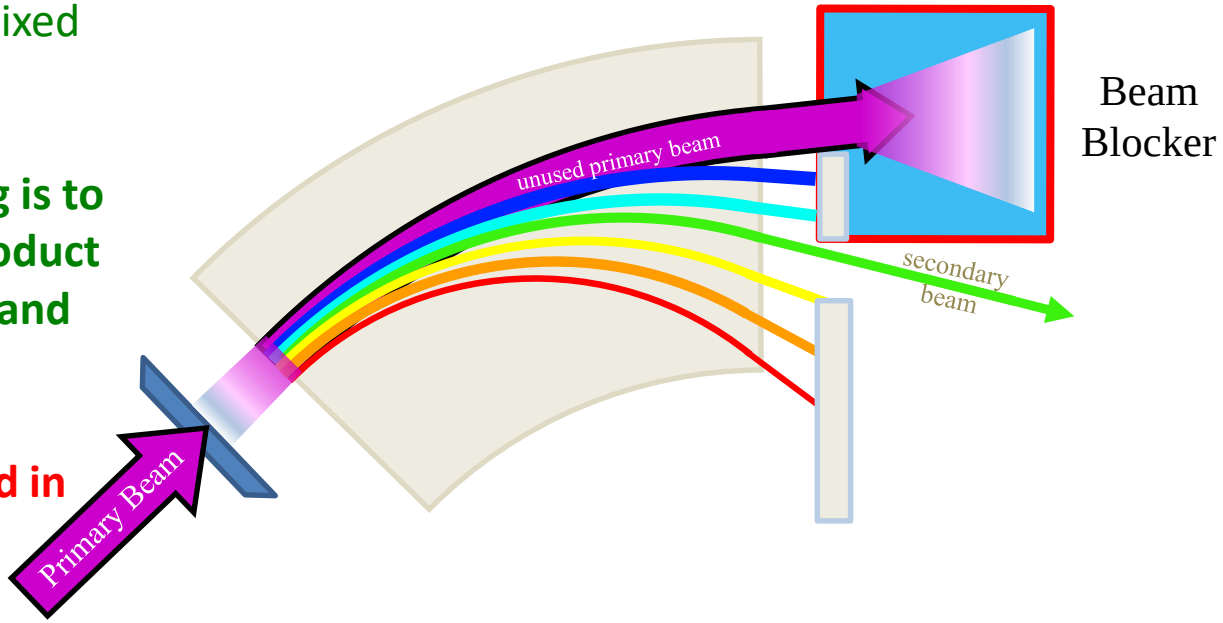
They will mostly be present as ions, or as dissolved gases in beam-dump cooling water.

The radionuclides will be all mixed together.

The goal of isotope harvesting is to collect and purify FRIB's byproduct radionuclides for use in basic and applied research.

TEC Funding of $2M requested in FY2020

- FRIB linac provides a "primary beam"
  - e.g. $^{48}Ca^{20+}$ 240 MeV/u ~33 pμA (2 x10^{14} particles per second)
- Primary beam hits a thin target (e.g. Be) and fragments
  - Reaction produces almost any nucleus with mass <50 and Z<Ti
    - » Probabilities for conversion are ~10^{-3} for masses near A = A_0, ~10^{-6} for other masses
    - » 90% of the primary beam does not react!
- Fragments are still moving, and a "secondary beam" is purified based on charge-to-mass
    - » Unreacted primary beam is directed to a "beam blocker" where many more nuclear reactions occur.



Latest SCGSR NP Award Recipient

Stacyann Stephanie Nelson Received the latest SCGSR Award

Final Research Area	Current Graduate Institution	Additional Graduate Education	Primary Graduate Thesis Advisor	Graduate Thesis Title	Host DOE Laboratory	Collaborating DOE Laboratory Scientist	Research Proposal Title
NP - Heavy Ion Nuclear Physics	Florida Agricultural and Mechanical University / Physics / Experimental Particle physics	The University of the West Indies / Physics / Physics (M.Phil. 5/2014)	Carol Scarlett / Florida Agricultural and Mechanical University / Physics / Associate professor Tallahassee, FL	J/Psi Photoproduction in Ultra-peripheral Au+Au collisions at PHENIX and 20 Picosecond TOF Detector R&D for sPHENIX	Brookhaven National Laboratory (BNL)	Mickey Chiu / Department of Physics / Physicist and Operation Manager NY	J/Psi Photoproduction in Ultra-peripheral Au + Au collisions at PHENIX and 20 Picosecond TOF Detector R&D for sPHENIX

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…"

Other News Items

- New Feds in DOE NP
  - Sharon Stephenson — Nuclear Structure & Astrophysics
  - Paul Sorensen — Fundamental Symmetries
  - Keith Jankowski — Nuclear Data
  - Arne Freyberger — Isotope Accelerator Facilities
  - John Neuhoff — Isotope Reactor Facilities
  - Linnette Quick (CONTR) — Program Assistant
- Jim Hawkins has retired
- Guidance for NP solicitations being updated; research will be prioritized over out-sized summer salary based on NIH model; strict adherence to guidance will be required for responsiveness to be satisfied
- New FOAs contemplated in QIS, Nuclear Data, AI/ML, Accelerator R&D

Other News Items

- Sharon Stephenson is stewarding the NP SC Graduate Student Research selection process
- Richard Witt is stewarding the annual Early Career Award selection Process
- Tanja Horn is NP's representative on a joint pan-SC-program FACA exercise examining activities in nuclear science relate to AI/ML
- A cross-cutting, cross-program lab only FOA on AI/ML is expected to be released in the near future
- The next Workshop for Applied Nuclear Data (WANDA) meeting is March 3-6, 2020 in Washington, D.C.
- There will be a workshop on "AI for Nuclear Physics" workshop at TJNAF on March 4-6,2020
- A joint NIH-SC-NP workshop on imaging technologies of mutual interest at TJNAF later this year. The Lead POC on the NP side is Cynthia Keppel.

Other News Items

- Manouchehr Farkhondeh is the NP POC for AI/ML and the SC Strategic Accelerator Technology Initiative
- Gulshan Rai is the NP POC for QIS/QC
- Upcoming Quantum Information PI Meeting, March 12-23, 2020
- Super Heavy Element (SHE) research review will take place at LBNL, April 6-8, 2020
- SBIR Phase III sales increased by roughly 70% this year to $2,848,078
- Barbara Jacak selected to be in the first-ever SC cohort of Distinguished Scientists

General Outlook

- The experience with FY18 and FY19 budgets maybe similar in the next budget cycle.
- 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!

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

The last thing needed right now…

Noun
(*plural* circular firing squads)
1.(idiomatic) A political party or other group experiencing considerable disarray because the members are engaging in internal disputes and mutual recrimination

Additional Information

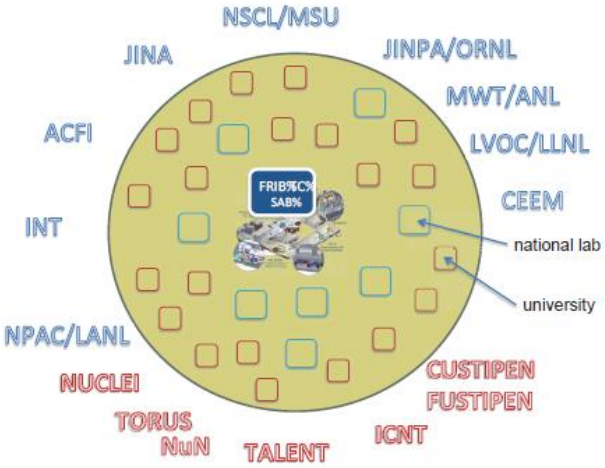
Nuclear Theory

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

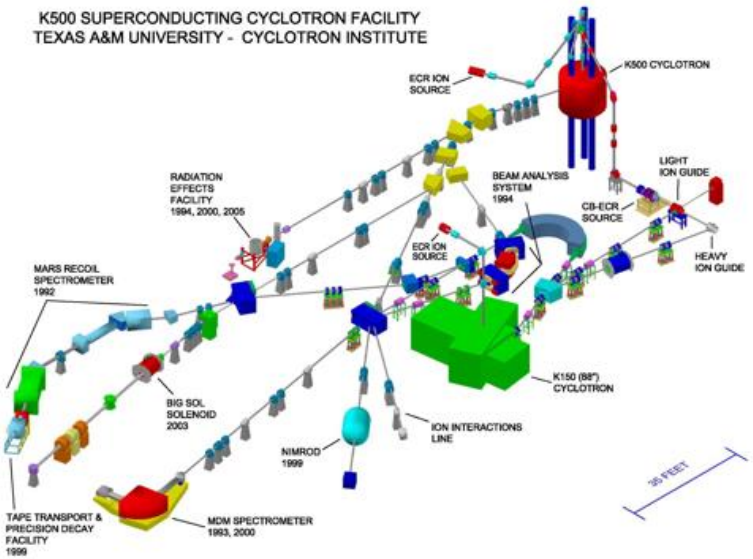


FRIB Theory Alliance

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

50 YEARS OF BEAM — exploring the nuclear frontier

CYCLOTRON INSTITUTE
TEXAS A&M UNIVERSITY

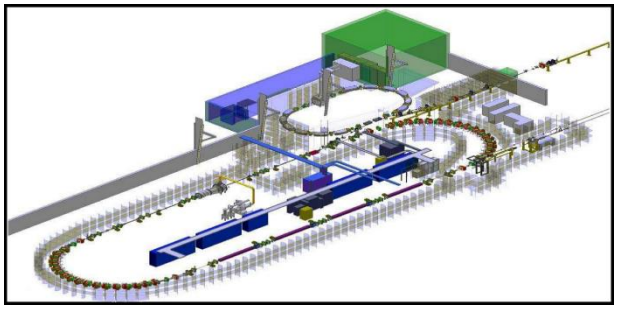


The Texas A&M University Cyclotron Institute jointly supported by DOE and the State of Texas focuses on conducting basic research, educating students in accelerator-based science and technology, and providing technical capabilities for a wide variety of applications in space science, materials science,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

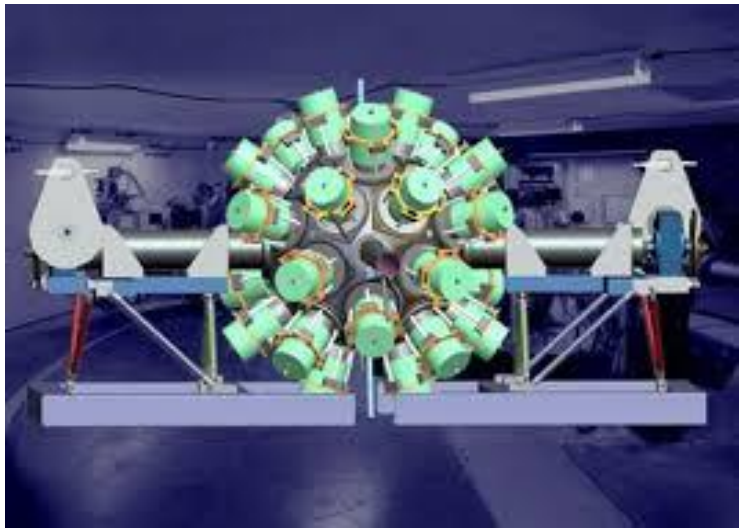
The 88 inch cyclotron also plays a crucial role in space radiation effects chip testing for the Air Force

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

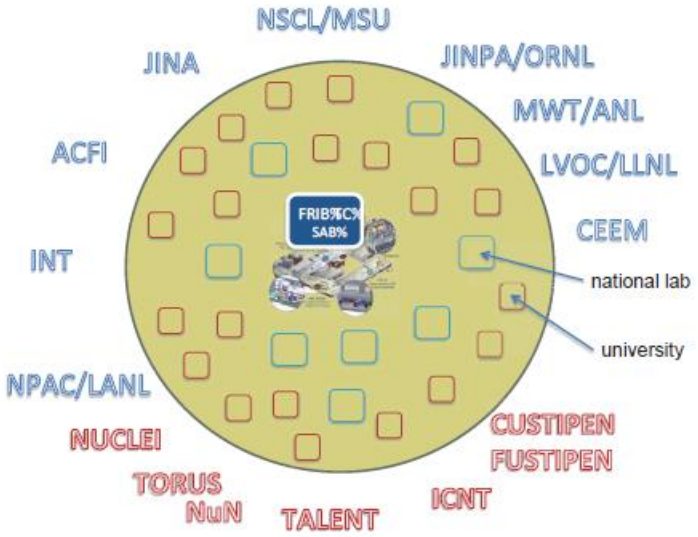
The Triangle Universities Nuclear Laboratory (TUNL) is Center of Excellence that focuses on low-energy nuclear physics research. TUNL is a consortium Duke University, North Carolina State University, and the University of North Carolina at Chapel Hill comprising about 30 faculty members, 20 postdocs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



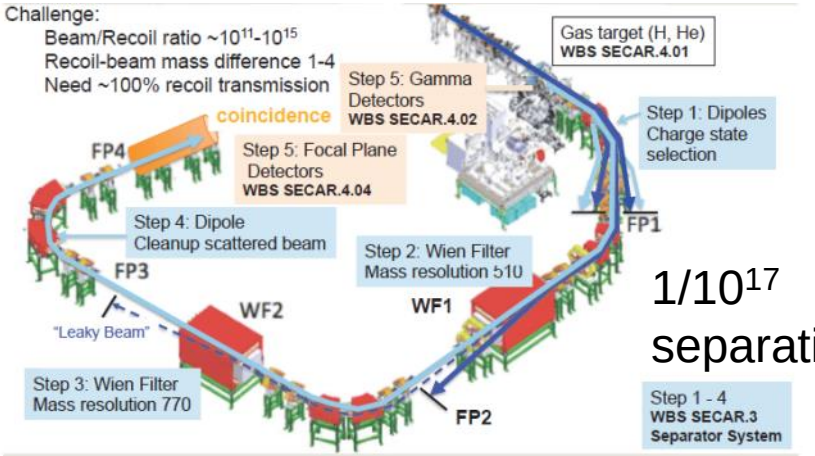
FRIB Instrumentation/Theory Effort Are Underway



GRETA CD3a 8/2018

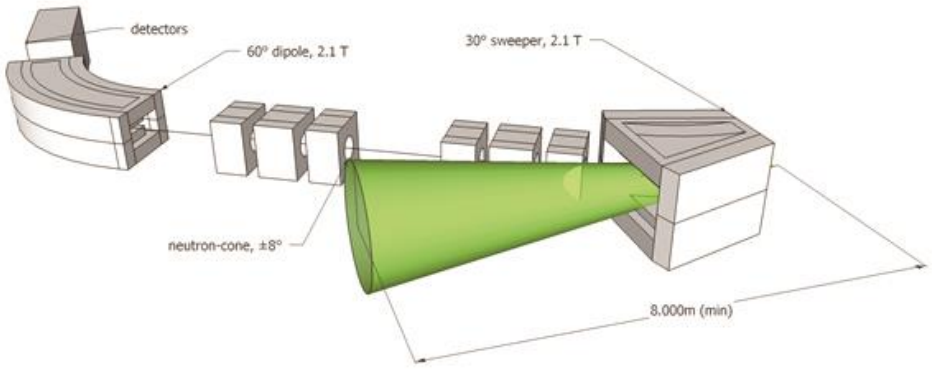


FRIB Theory Alliance



$1/10^{17}$ separation

SECAR Complete FY20/21



Pre-Conceptual High Rigidity Spectrometer (HRS)