



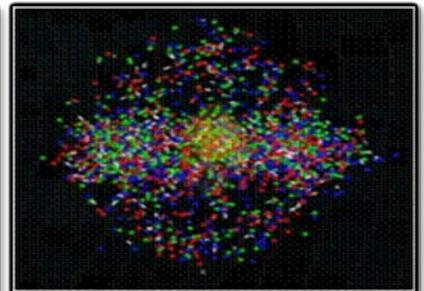
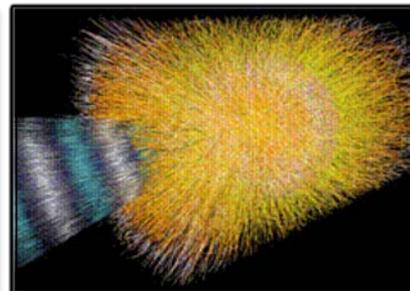
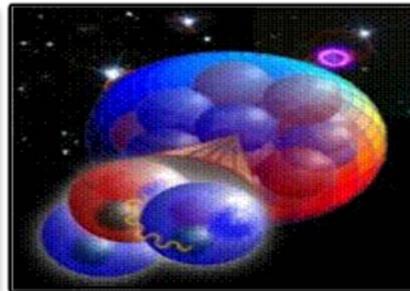
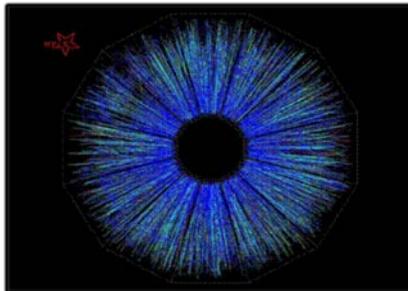
U.S. DEPARTMENT OF  
**ENERGY**

Office of  
Science

## Perspectives from DOE Nuclear Physics

NSAC Meeting  
October 15, 2015

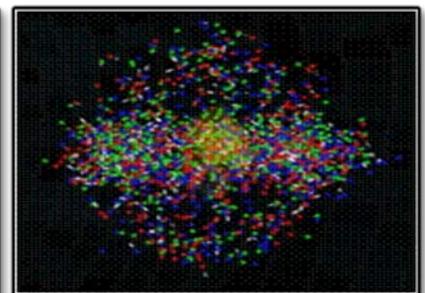
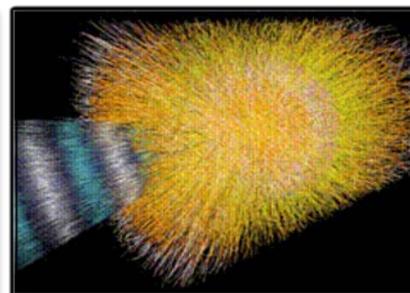
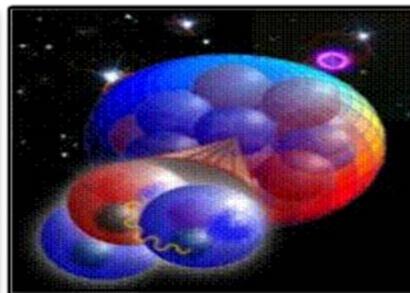
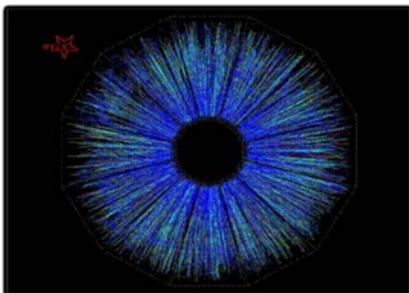
Dr. Timothy J. Hallman  
Associate Director for Nuclear Physics  
DOE Office of Science



Discovering, exploring, and understanding all forms of nuclear matter

## The Scientific Challenges

- The existence and properties of nuclear matter under extreme conditions, including that which existed at the beginning of the universe
- The exotic and excited bound states of quarks and gluons, including new tests of the Standard Model
- The ultimate limits of existence of bound systems of protons and neutrons
- Nuclear processes that power stars and supernovae, and synthesize the elements
- The nature and fundamental properties of neutrons and the neutrino and their role in the evolution of the early universe



# The Nuclear Science Community Stewarded by DOE NP

## National User Facilities

- RHIC (BNL)
- CEBAF (TJNAF)
- ATLAS (ANL)
- ~3,000 users

## Research Groups

- 9 National Laboratories
- 90 Universities

## NP Workforce

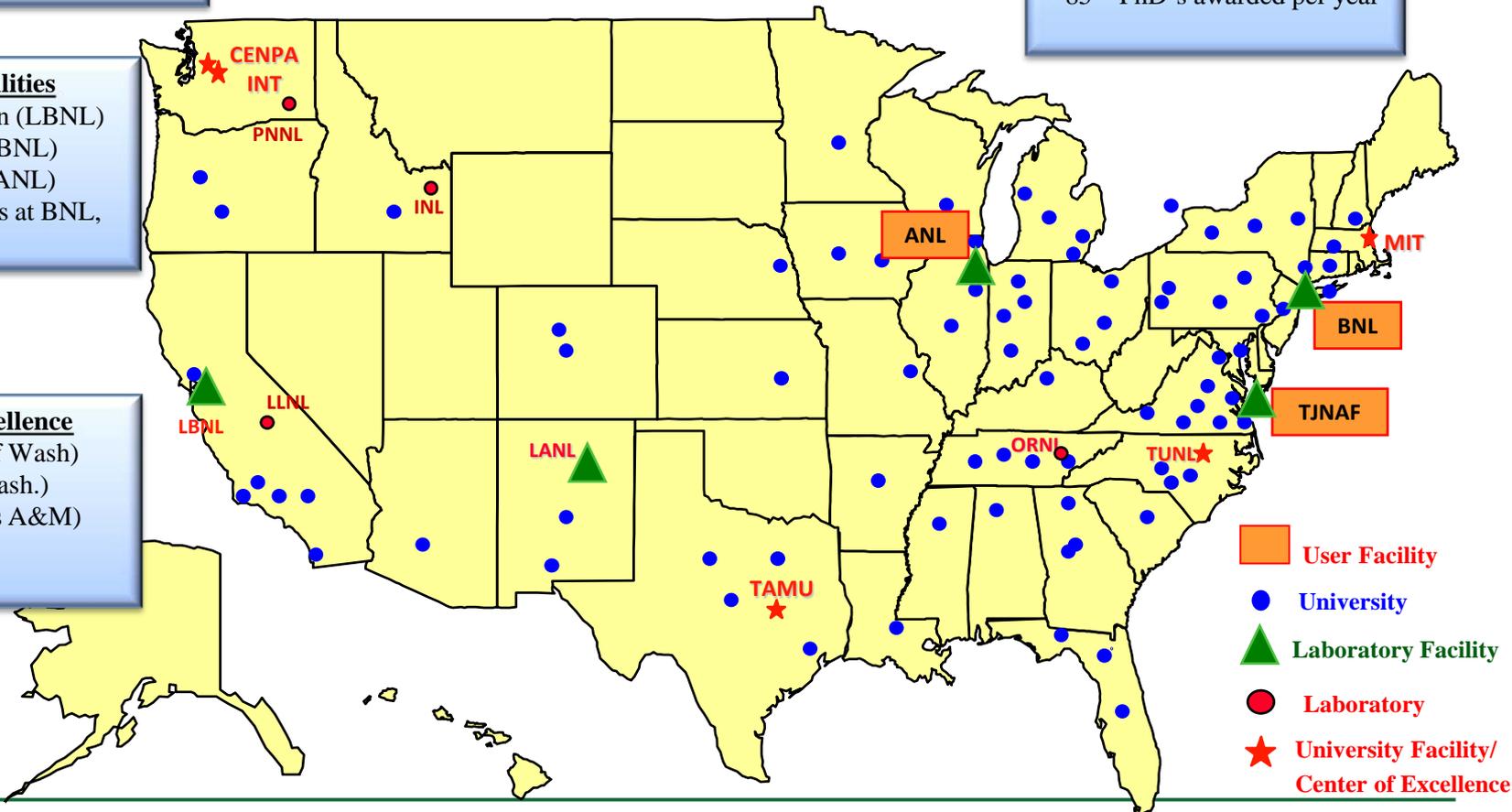
- ~700 Faculty & Lab Res Staff
- ~320 Post-docs
- ~520 Graduate Students
- ~1000 Technical/admin
- ~100 Undergraduate Students
- ~ 85 PhD's awarded per year

## Other Lab. Facilities

- 88-Inch Cyclotron (LBNL)
- 200 MeV BLIP (BNL)
- 100 MeV IPF (LANL)
- Hot Cell Facilities at BNL, LANL, ORNL

## Centers of Excellence

- CENPA (U. of Wash)
- INT (U. of Wash.)
- TAMU (Texas A&M)
- TUNL (Duke)
- REC (MIT)



# FY2015 Long Range Plan Exercise Completed

**NSAC partnership with the Division of Nuclear Physics of the APS to tap the full intellectual capital of the U.S. nuclear science community in identifying exciting, compelling science opportunities and a strategic plan for the next 5-10 years:**

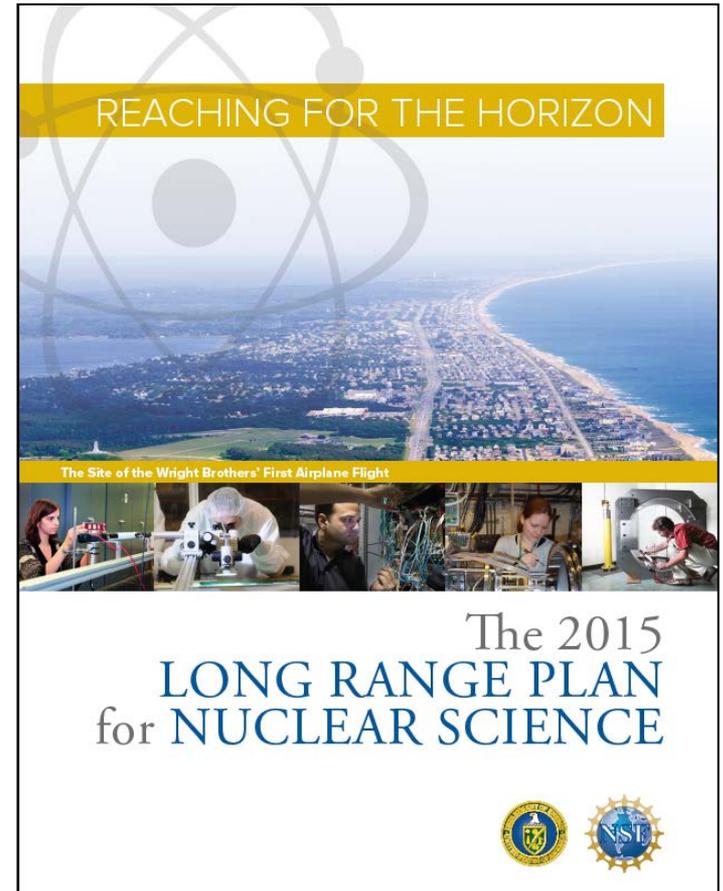
**Nuclear Structure & Nuclear Astrophysics meeting, Nuclear Structure**  
*Conveners:* Mark Riley, Charlotte Elster; *Nuclear Astrophysics Conveners:* Hendrik Schatz and Michael Wiescher *Venue:* Mitchell Institute, Texas A&M University, Aug. 21-23, 2014 *Meeting website:* <http://www.lecmeeting.org/>

**Hadron and Heavy Ion QCD meeting, QCD Heavy Ion** *Conveners:* Paul Sorensen and Ulrich Heinz, *QCD Hadron Conveners:* Haiyan Gao and Craig Roberts *Venue:* Temple University, Sept. 13-15, 2014  
*Website:* <https://phys.cst.temple.edu/qcd>

**Fundamental symmetries, Neutrinos, Neutrons, and the relevant Nuclear Astrophysics, Conveners:** Hamish Robertson, Michael Ramsey-Musolf *Dates:* Sept. 28-29, 2014 *Venue:* Crowne Plaza, O'Hare Airport  
*Website:* <http://fsnutown.phy.ornl.gov/fsnuweb/index.html>

**Nuclear Theory Computing:**  
[High performance computing](#) (Computation in nuclear physics), Washington DC, July 14-15, 2014

**Education [NSF scope - Workforce Training in DOE] and Innovation... across all areas of nuclear physics** *Conveners:* Michael Thoennessen, Graham Peaslee *Venue:* NSCL, Michigan State University, Aug. 6-8, 2014;  
*Website:* <http://meetings.nslc.msu.edu/Education-Innovation-2014>



**Resolution Meeting: Spring of 2015**

**Long Range Plan: October 15, 2015**

# NSACI Strategic Planning Exercise Completed

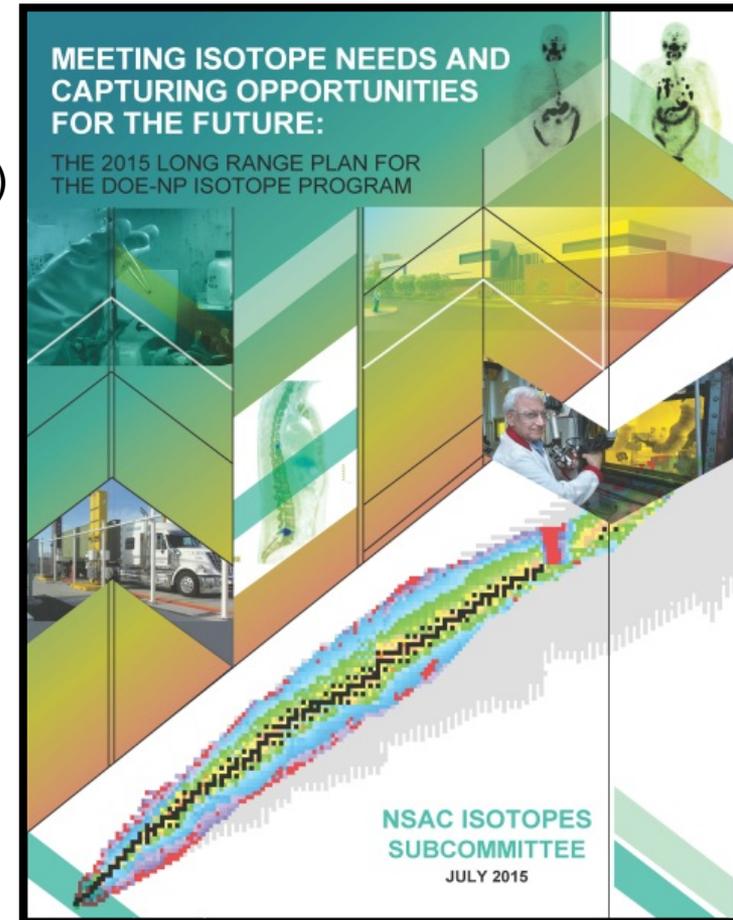
## New Report released July 20, 2015:

- All prior recommendations addressed

## New recommendations:

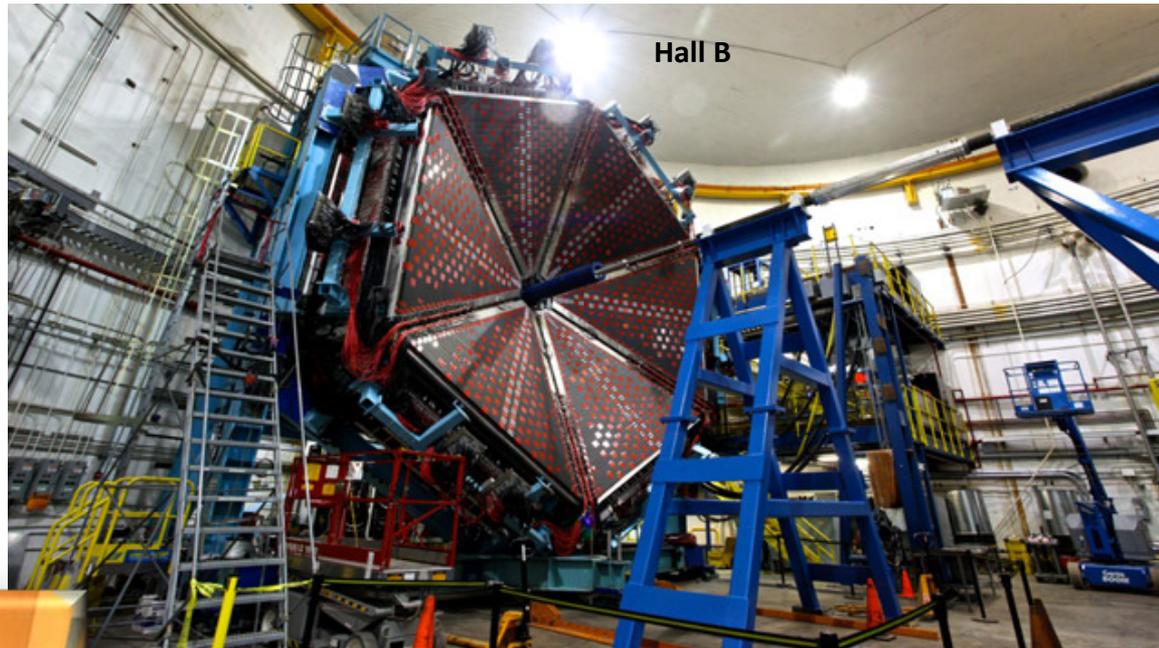
- Significant increase in R&D funding
  - Continue R&D on alpha-emitters (Ac-225, At-211)
  - High specific activity theranostic isotopes
  - Electron accelerators for isotope production
  - Irradiation materials for targets
- Complete creation of stable isotope capability
- Increase in infrastructure investments and operating base
  - Isotope harvesting at FRIB
  - Separator for radioactive isotopes
  - BLIP intensity upgrade and second target station
  - IPF intensity, stability and energy upgrades
- Continue integration of university facilities

## New 2015 LRP for the DOE-NP Isotope Program



# The 12 GeV CEBAF Upgrade at TJNAF is 96% Complete

Project completion (CD-4B) is planned by the end of FY 2017

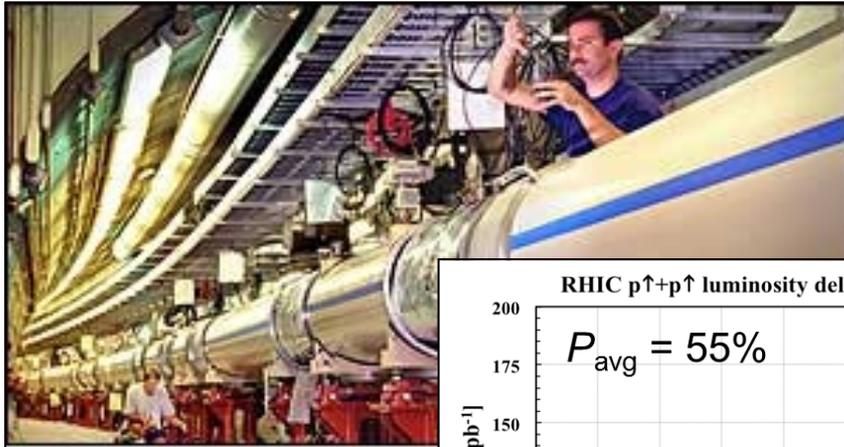


With the completion of the 12 GeV CEBAF Upgrade, researchers will address:

- The search for exotic new quark—anti-quark particles to advance our understanding of the strong force.
- Evidence of new physics from sensitive searches for violations of nature's fundamental symmetries.
- A detailed 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.

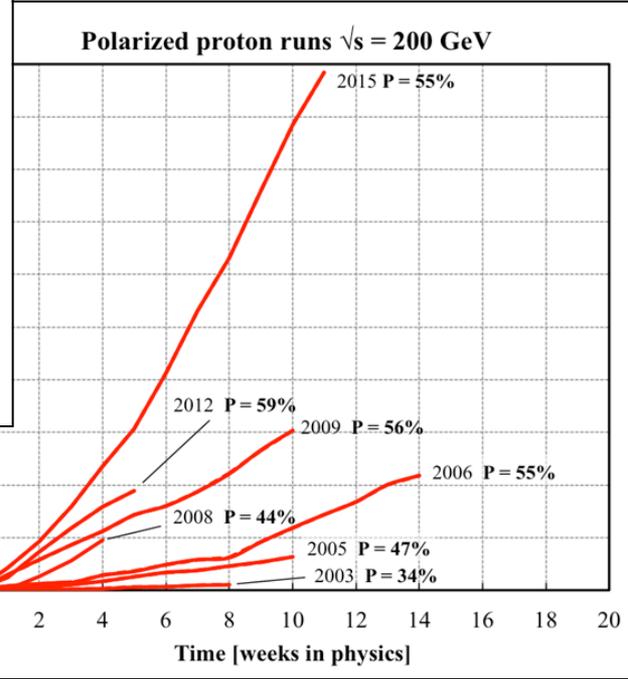
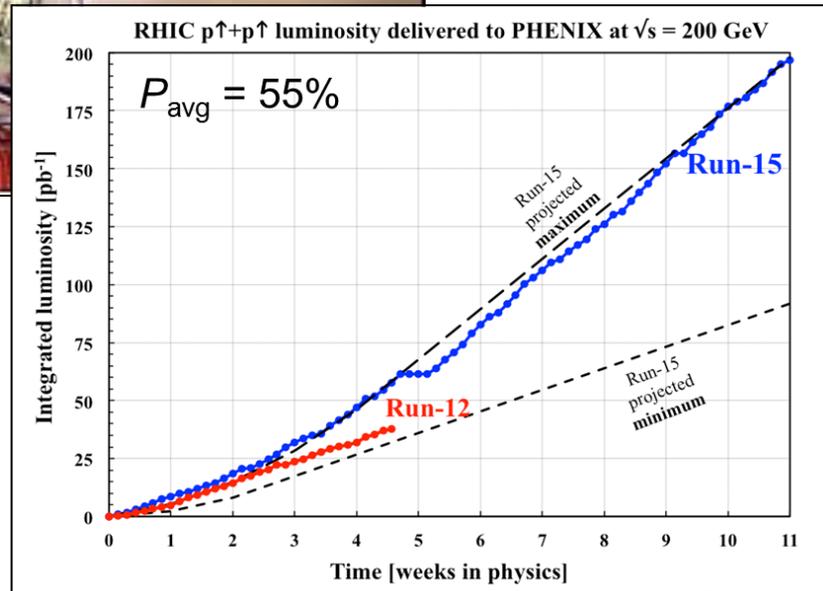


# RHIC Machine Performance Continues to Set New Records



Run-15  $p\uparrow + p\uparrow$  at  $\sqrt{s} = 200$  GeV

**Déjà vu**  
all over again  
Run-15 integrated  
luminosity at  
 $\sqrt{s} = 200$  GeV  
exceeds sum of  
all previous runs



No other facility worldwide, existing or planned, can rival RHIC in range and versatility as a heavy ion collider. It is the only polarized proton collider in the world.

# The Facility for Rare Isotope Beams is ~ 50% Complete

FRIB – September 16, 2015  
 (TPC: \$635.5M DOE + \$94.5M MSU)  
 Project Completion: 3Q FY 2022

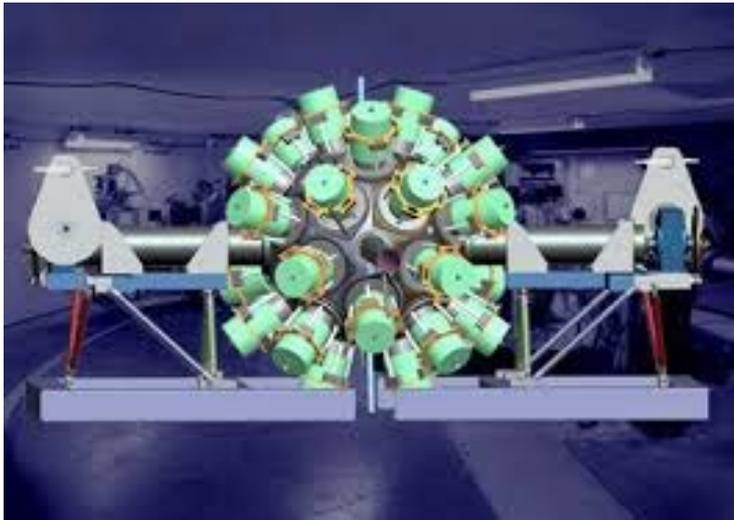


FRIB	PYs	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	TOTAL
DOE TPC \$000s	51,000	22,000	55,000	90,000	100,000	100,000	97,200	75,000	40,000	5,300	635,500

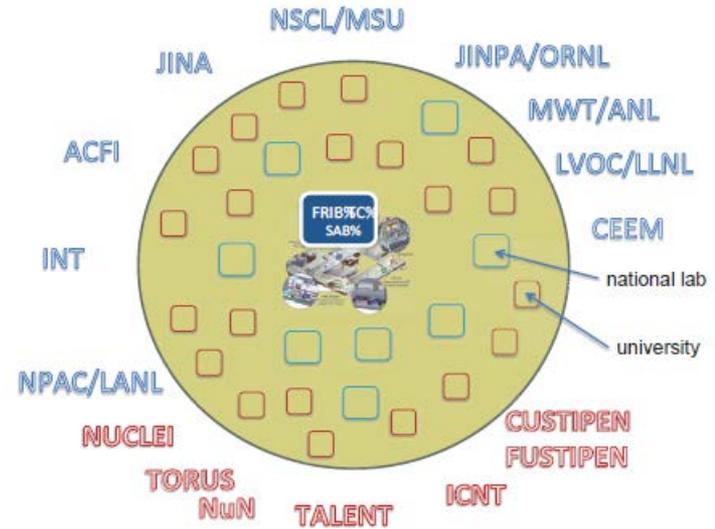
# Progress on the Facility for Rare Isotope Beams



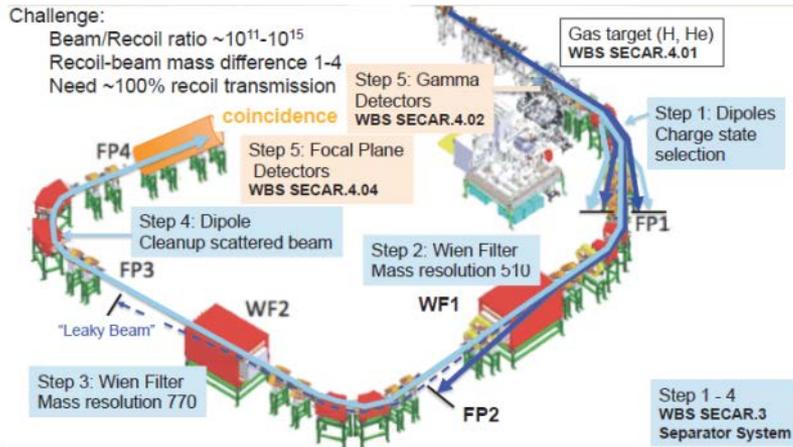
# FRIB Instrumentation/Theory Effort is Just Getting Underway



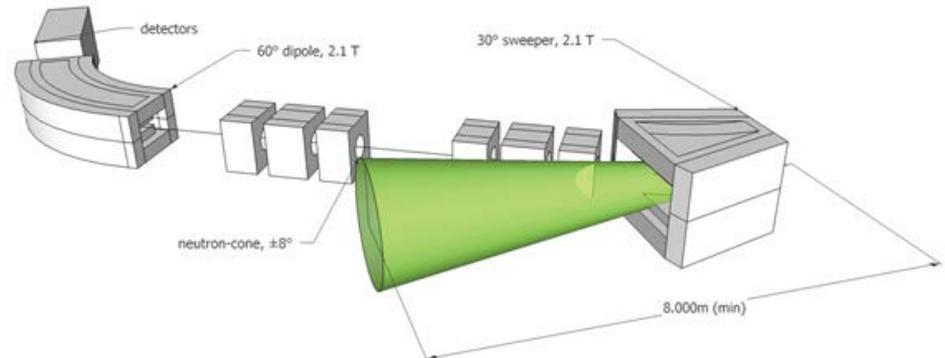
**GRETA**



**FRIB Theory Alliance**

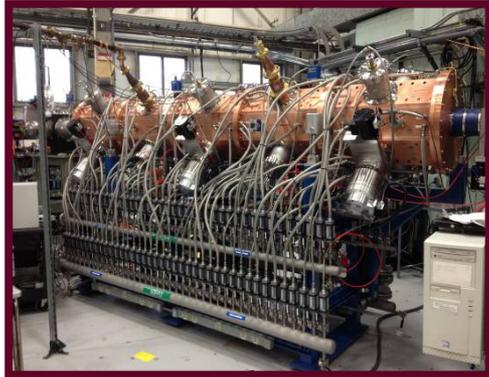


**SECAR**



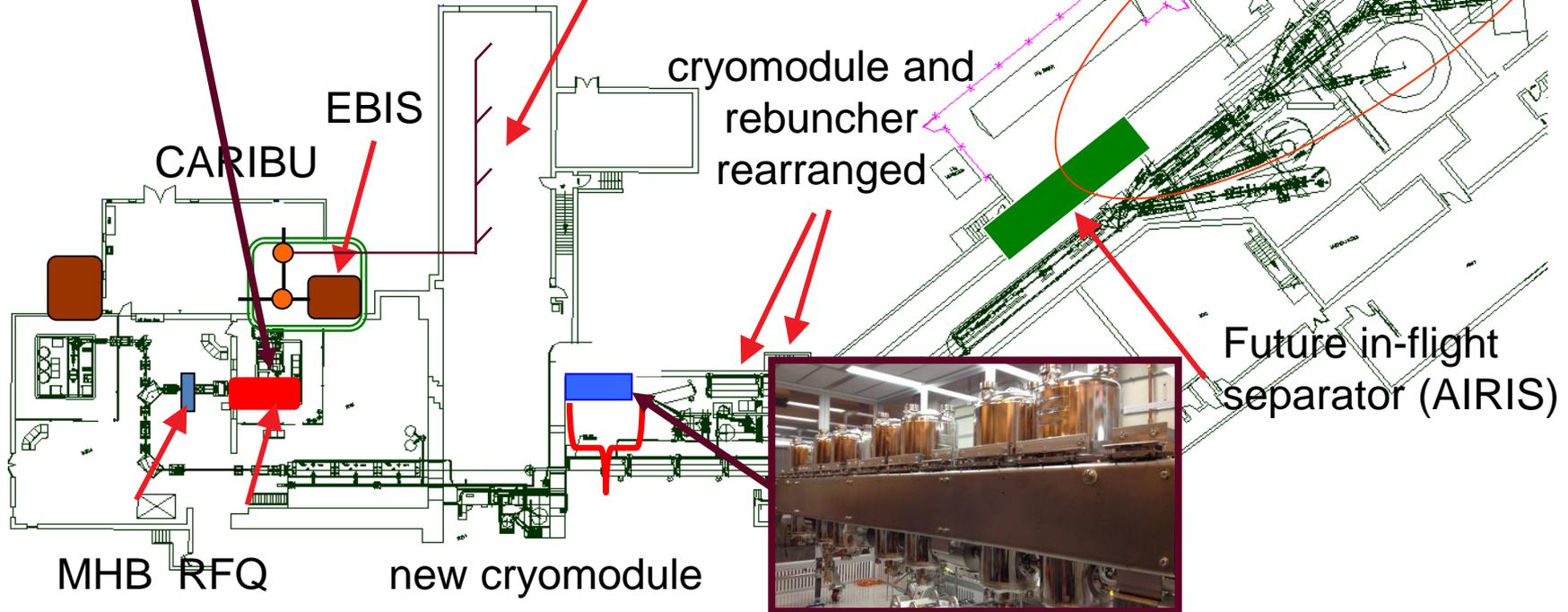
**Pre-Conceptual High Rigidity Spectrometer (HRS)**

# ATLAS layout after recent upgrades



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

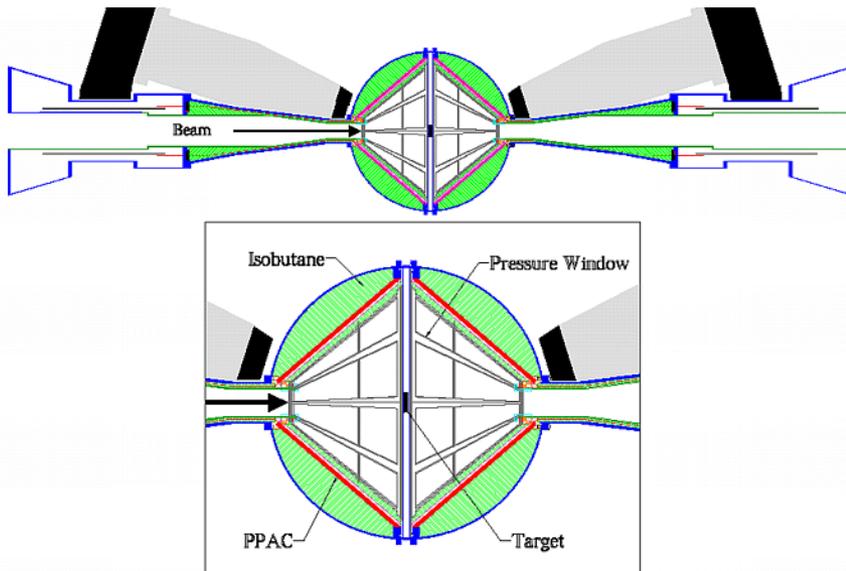
New low-energy experimental hall



# CHICO-II and GRETINA at ATLAS

## Programs:

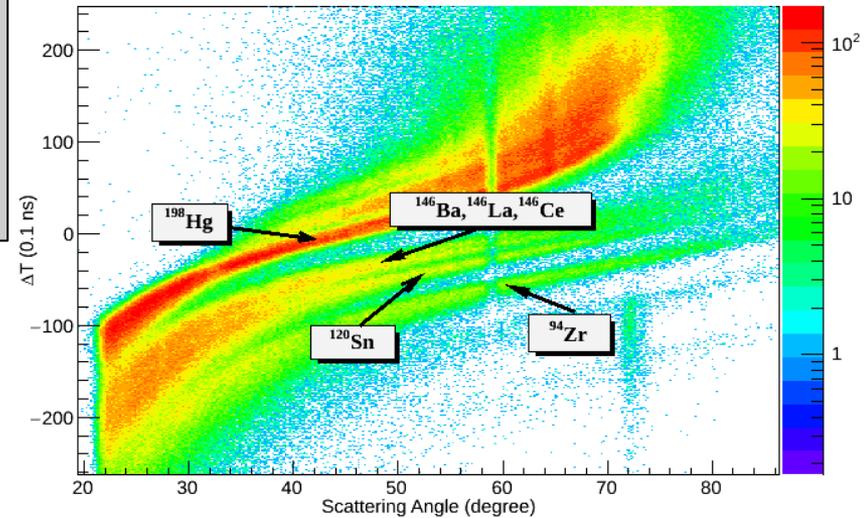
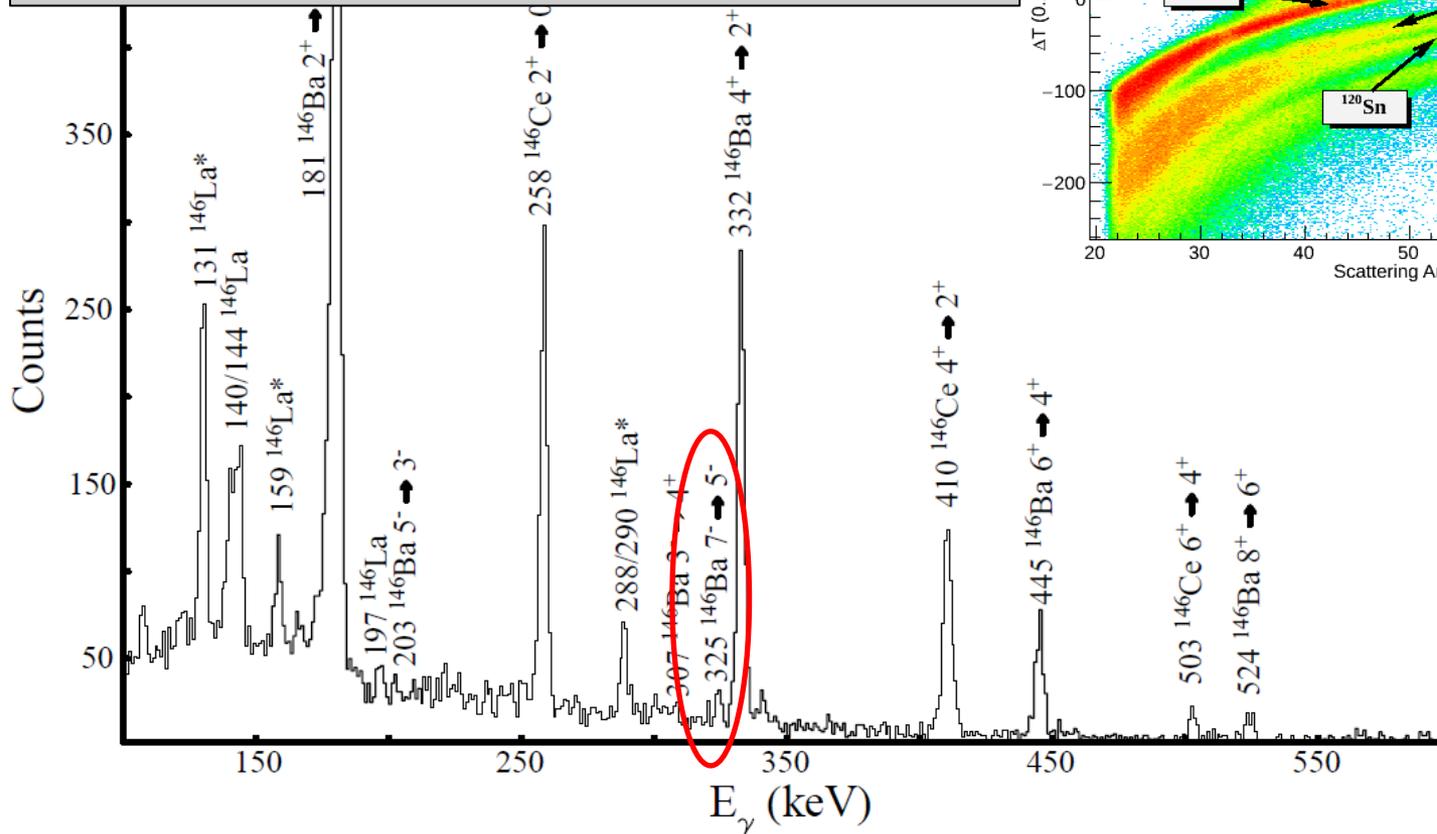
- Coulomb Excitation of stable and CARIBU beams;
- Structure studies of neutron-rich nuclei using deep-inelastic reactions;
- CHICO-II: high segmentation for both  $\theta$  ( $1^\circ$ ) and  $\phi$  ( $1.4^\circ$ )
- GRETINA: about 3.50(2)% absolute efficiency at 1332.5 keV



# $^{146}\text{Ba}$ Coulomb Excitation

Statistics ~ 100 times higher than previously obtained

- higher yield
- more stable operation
- more efficient post-acceleration
- better diagnostics



$^{146}\text{Ba}$  is predicted to octupole deformed. The observed coincidence  $\gamma$  spectra allow extraction of an E3 transition probability to verify the theory.



# Preparations for an NP Stewarded Neutrino-less Double Beta Decay Experiment

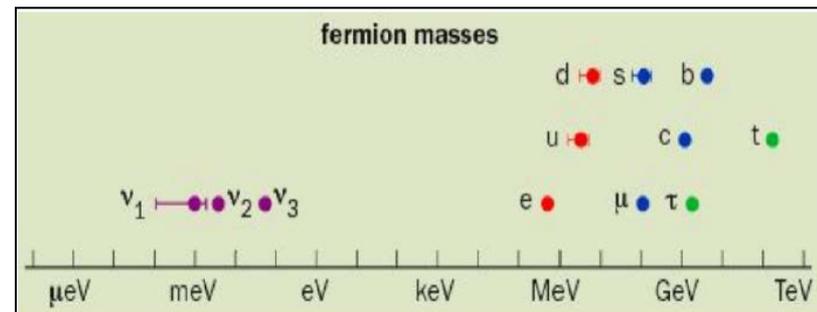
With techniques that use nuclear isotopes inside cryostats, often made of ultra-clean materials, scientists are “tooling up” to study whether neutrinos are their own anti-particle. NSAC charged to provide additional guidance on effective strategy for implementing a possible 2<sup>nd</sup> generation U.S. experiment



Mandrel insertion in MJD electroforming lab

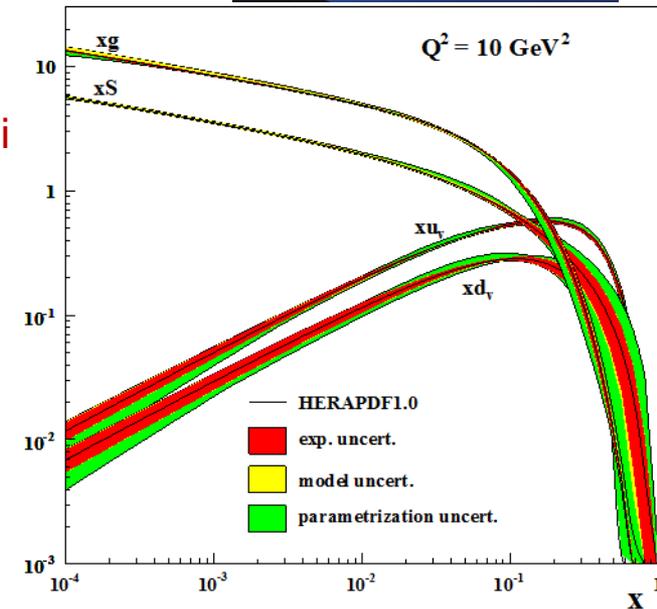
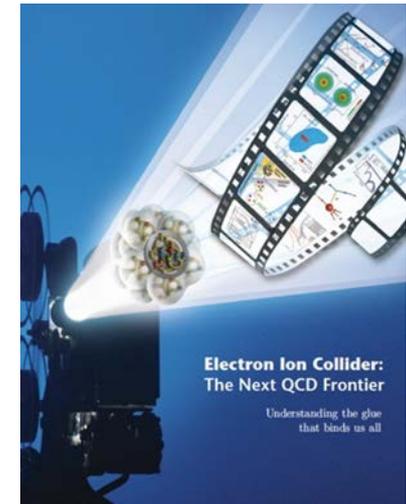
“Grand Challenge” science questions that will be addressed:

- Is the neutrino its own anti-particle?
- Why is there more matter than anti-matter in the present universe?
- Why are neutrino masses so much smaller than other elementary fermions?



# The Long Term Future of QCD: Understanding the Glue That Binds Us All

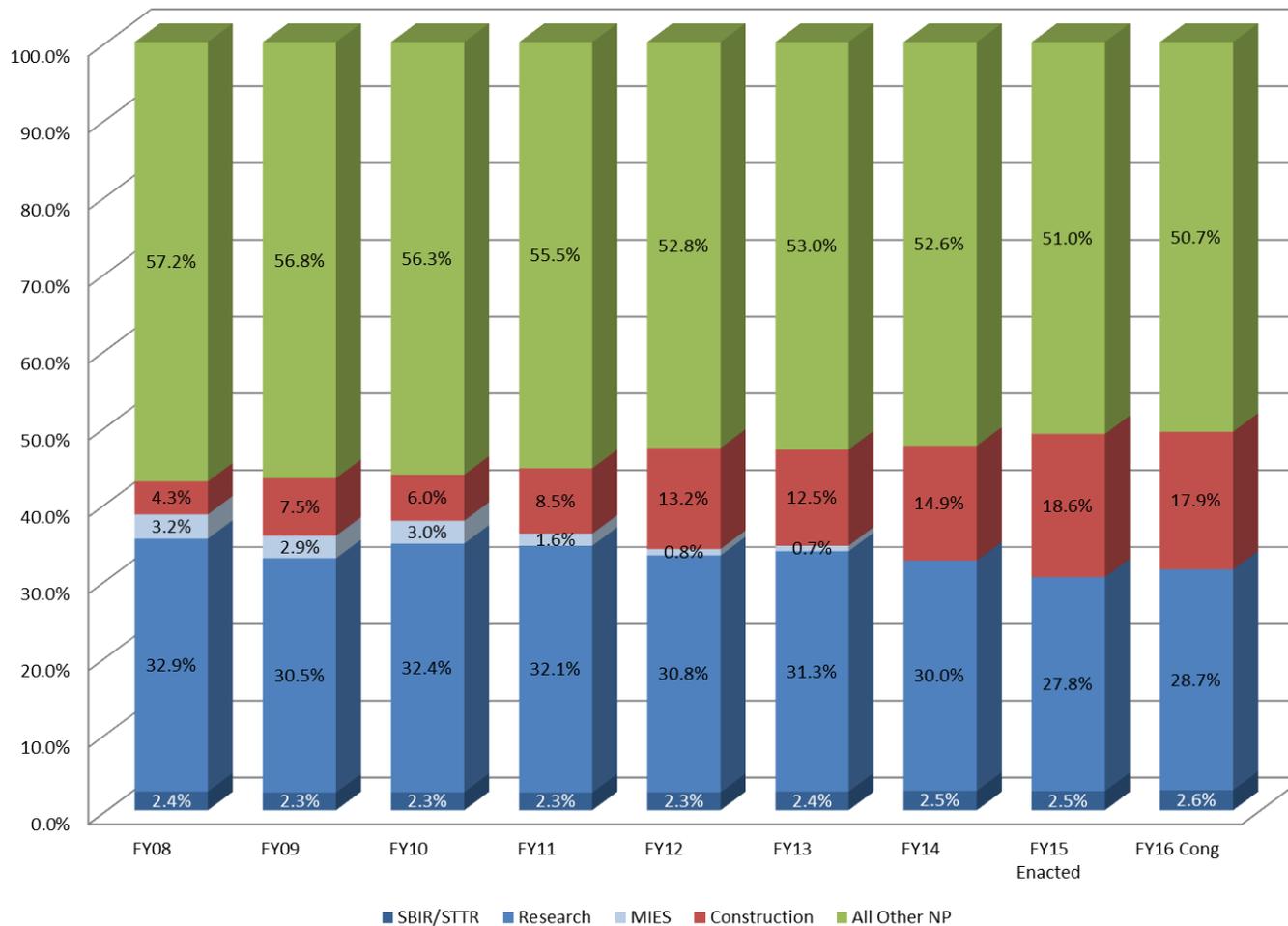
- Proton (and nuclei) and black holes are the only fully relativistic (high enough energy density to excite the vacuum) stable bound systems in the universe. Protons can be studied in the laboratory.
- Protons are fundamental to the visible universe (including us) and their properties are dominated by emergent phenomena of the self-coupling strong force that generates high density gluon fields:
  - The mass of the proton (and the visible universe)
  - The spin of the proton
  - The dynamics of quarks and gluons in nucleons and nuclei
  - The formation of hadrons from quarks and gluons
- The study of the high density gluon field that is at the center of it all requires a high energy, high luminosity, polarized Electron Ion Collider



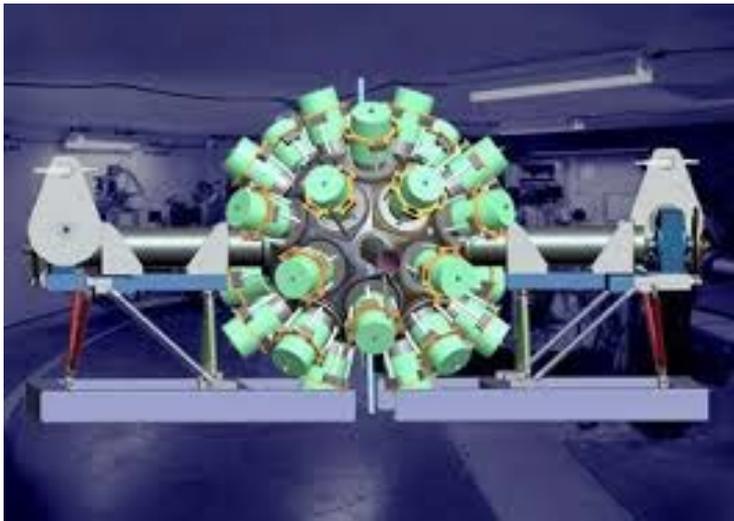
The 2013 NSAC *Subcommittee on Future Facilities* identified the physics program for an Electron-Ion Collider as **absolutely central** to the nuclear science program of the next decade.

# Trends in Research and MIEs as a Percentage of the NP Budget FY 2008-FY2016

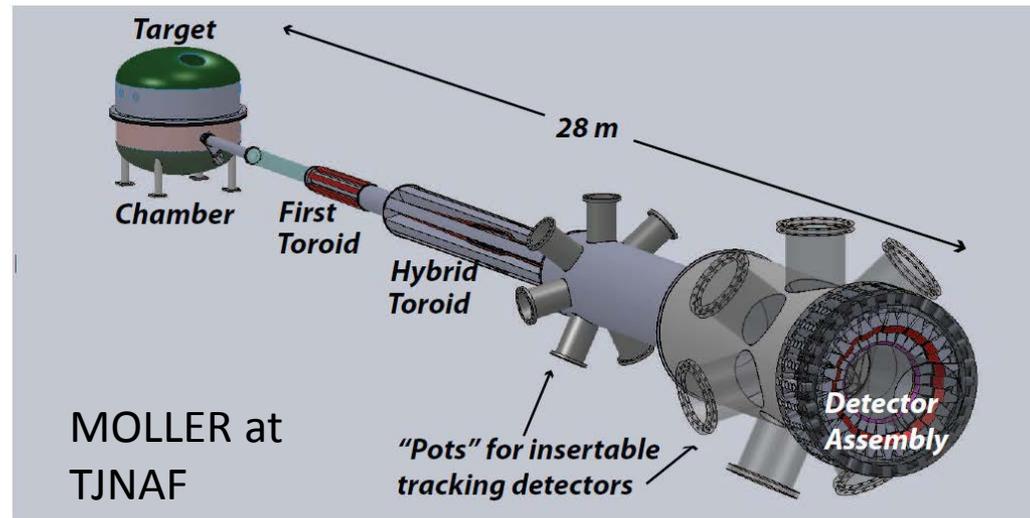
Constructing major new research tools has constrained other aspects of the NP program



# Mid-Scale Instrumentation Is Essential to Extract the Science

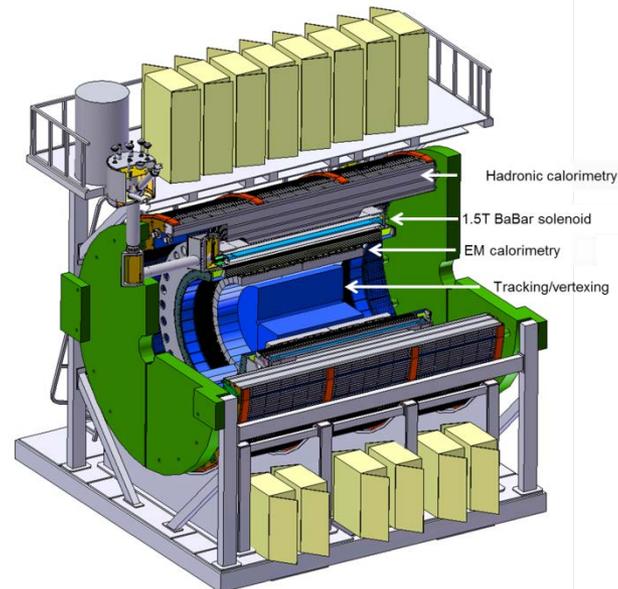


**GRETA at FRIB**



**MOLLER at  
TJNAF**

Mid-Scale instrumentation plays an essential role in realizing the full science return on investment at National User Facilities. A few examples of ideas from the community are shown.



**sPHENIX at  
RHIC**

# Nuclear Theory News

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The Office of Nuclear Physics (NP), on the basis of a peer review, has selected the following Topical Collaborations (to start in FY 2016) for funding recommendation:

Coordinated Theoretical Approach to Transverse Momentum Dependent Hadron Structure in QCD (TMD Collaboration)

Principal Investigator/Project Director: Jianwei Qiu; Lead Institution: Brookhaven National Laboratory  
Participating Institutions: Duke University, Jefferson Laboratory, Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, Los Alamos National Laboratory, MIT, New Mexico State University, Penn State University at Berks, Old Dominion University, Temple University, University of Arizona, University of Kentucky, University of Maryland, University of Virginia

Nuclear Theory for Double-Beta Decay and Fundamental Symmetries (DBD Collaboration)

Principal Investigator/Project Director: Jonathan Engel; Lead Institution: University of NC at Chapel Hill  
Participating Institutions: Central Michigan University, College of William and Mary, Iowa State University, Michigan State University, Los Alamos National Laboratory, Lawrence Livermore National Laboratory, San Diego State University, University of California Berkeley, University of Massachusetts, University of Tennessee

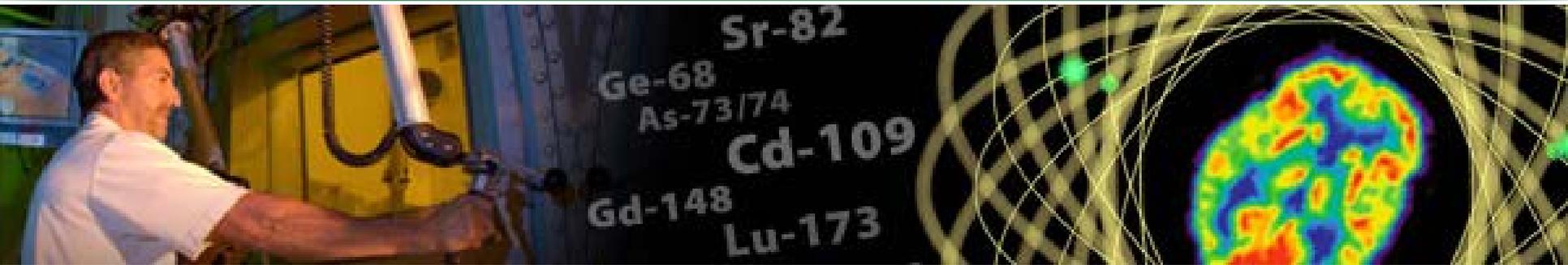
Beam Energy Scan Theory Collaboration (BEST Collaboration)

Principal Investigator/Project Director: Swagato Mukherjee; Lead Institution: Brookhaven National Laboratory  
Participating Institutions: Indiana University, Lawrence Berkeley National Laboratory, McGill University, Michigan State University, MIT, North Carolina State University, Ohio State University, Stony Brook University, University of Chicago, University of Connecticut, University of Houston, University of Illinois at Chicago

Topical Collaborations are fixed-term, multi-institution collaborations established to investigate a specific topic in nuclear physics of special interest to the community, which is well aligned with programmatic NP goals.

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# Isotope Program Mission



## The mission of the DOE Isotope Program is threefold

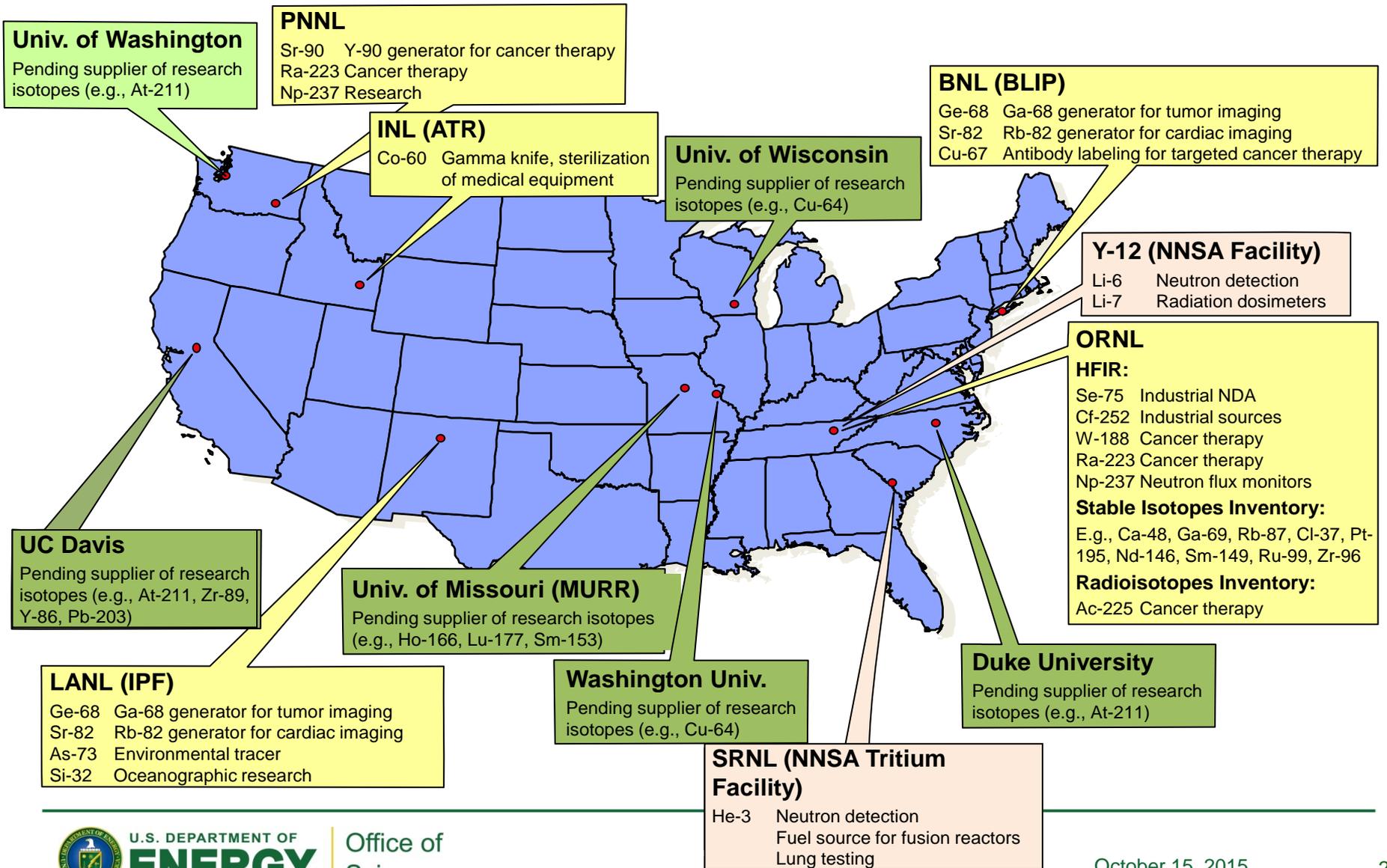
- Produce and/or distribute radioactive and stable isotopes that are in short supply, associated byproducts, surplus materials and related isotope services.
- Maintain the infrastructure required to produce and supply isotope products and related services.
- **Conduct R&D on new and improved isotope production and processing techniques which can make available new isotopes for research and applications.**

**Produce isotopes that are in short supply only –  
the Isotope Program does not compete with industry**

**More than 225 customers in FY 2015**

**More than 400 shipments in FY 2015**

# DOE Isotope Program Production Sites



# Next Workshop on Isotope Federal Supply and Demand, November 9, 2015

## Valuable for isotope demand forecasting

- Armed Research Institute
- Defense Logistics Agency
- Defense Threat Reduction Agency
- Department of Agriculture
- DOE/National Isotope Development Center
- DOE/National Nuclear Security Administration
- DOE/New Brunswick Laboratory
- DOE/Office of Fossil Energy-Oil and Natural Gas
- DOE/Office of Intelligence
- DOE/Office of Nuclear Energy
- DOE/Office of Science
- Department of Homeland Security
- Department of State
- Department of Transportation
- Federal Bureau of Investigation
- Food and Drug Administration
- National Aeronautics and Space Administration
- National Institutes of Health
- National Institute of Standards and Technology
- National Science Foundation
- National Security Staff
- Office of Science & Technology Policy
- Office of the Director of National Intelligence



# A Serious Challenge: Domestic Stable Isotopes Inventory

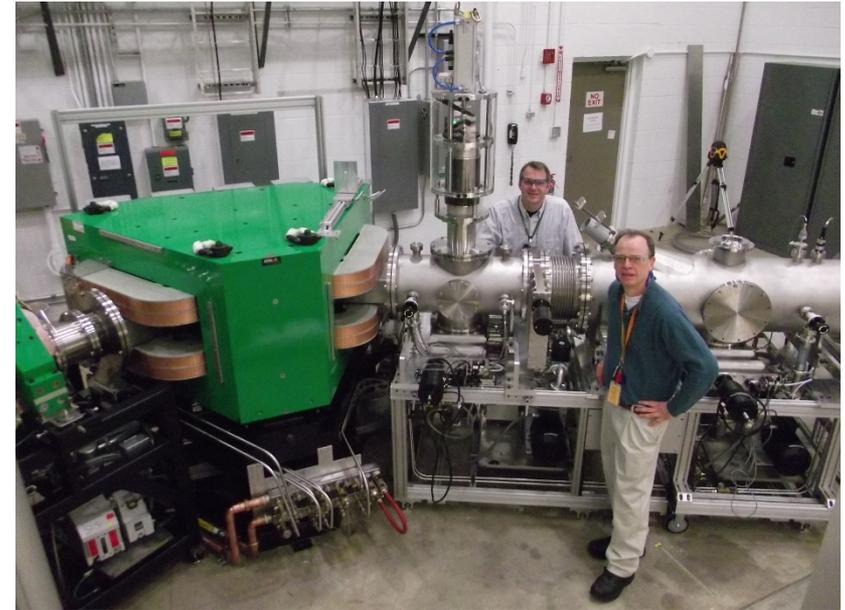
- Currently there is no existing domestic broad-scope U.S. enrichment capability.
- Existing Inventory is from Y12 Calutron enrichment from 1945 – 1998.
- The inventory of 11 stable isotopes has been exhausted.
- These are unique materials with few other suppliers; demand is high (500 POs in FY14).
- U.S. is dependent upon Russia for new production of stable enriched isotopes.



The U.S. Stable Isotope Inventory at ORNL

# Solution: Stable Isotope Production Facility (SIPF)

- 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.”
- SIPF would mitigate U.S. foreign dependence of stable isotope enrichment



Notional Cost Range: \$9.5M-\$10.5M

Notional time frame for completion: FY 2020

SIPF Received Mission Need CD0 9/4/2015

The SIPF directly supports the DOE Isotope Program mission, restoring domestic capability that has been lacking since 1998. Renewed enrichment capability will benefit nuclear and physical sciences, industrial manufacturing, homeland security, and medicine.

# The FY16 Request for Nuclear Physics

(\$ in 000s)	FY 2014 Enacted	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Research	170,668	165,828	179,311	+13,483
User Facility Operations	276,887	280,663	293,304	+12,641
Other Operations	24,120	24,313	24,995	+682
Projects	80,500	106,500	107,500	+1,000
Other	16,963	18,196	19,490	+1,294
<b>TOTAL NP</b>	<b>569,138</b>	<b>595,500</b>	<b>624,600</b>	<b>+29,100</b>

- **Research** – Support for university and lab research increases across the program to address important opportunities identified by the research community, and to enhance high priority research that will foster significant advances in nuclear structure, nuclear astrophysics, the study of matter at extreme conditions, hadronic physics, fundamental properties of the neutron, and neutrinoless double beta decay.
- **User Facility Operations** – Operations of RHIC are maintained at the FY 2015 level with increases provided for critical staff, equipment, and materials required for reliable operations and support of research focused on characterizing the perfect quark-gluon liquid discovered in collisions of relativistic heavy nuclei. Beam development and commissioning activities continue at CEBAF as the 12 GeV CEBAF Upgrade project approaches completion, and scientific instrumentation is implemented in the experimental halls in preparation for the full start of the physics program in FY 2017. Operations of ATLAS are optimized, exploiting the new capabilities of CARIBU and completing the campaign with the GRETINA gamma ray spectrometer.
- **Other Operations** – Requested funding for the Isotope Program maintains mission readiness for the production of radioisotopes.
- **Projects** – 12 GeV CEBAF Upgrade and FRIB construction are supported according to baselined profiles.
- **Other** – Increased funding is provided for the SBIR/STTR programs consistent with the legislative mandate.



# Nuclear Physics

## FY 2016 Budget Status

	FY 2014 Approp. with SBIR/ STTR	FY 2015 Enacted	FY 2016 President's Request	FY 2016 Request vs. FY 2015	FY 2016 House Mark	FY 2016 House vs. Request	FY 2016 Senate Mark	FY 2016 Senate vs. Request
<b>Nuclear Physics</b>								
<b>Operation and maintenance</b>								
Medium Energy	146,963	150,892	158,062	+7,170	158,062	-		
<i>TJNAF Operations</i>	94,494	97,050	100,170	+3,120	100,170	-		
Heavy Ions	199,355	199,966	211,366	+11,400	204,931	-6,435		
<i>RHIC Operations</i>	165,072	166,072	174,935	+8,863	168,500	-6,435	174,935	-
Low Energy	76,616	75,196	79,788	+4,592	79,788	-		
<i>ATLAS Operations</i>	17,321	17,541	18,199	+658	18,199	-		
Nuclear Theory	46,300	43,096	46,220	+3,124	46,220	-		
Isotope Program	19,404	19,850	21,664	+1,814	21,664	-		
Undistributed	-	-	-	-	-	-	314,065	
<b>Total, Operation and maintenance</b>	<b>488,638</b>	<b>489,000</b>	<b>517,100</b>	<b>+28,100</b>	<b>510,665</b>	<b>-6,435</b>	<b>489,000</b>	<b>-28,100</b>
<b>Construction</b>								
14-SC-50 Facility for Rare Isotope Beams	55,000	90,000	100,000	+10,000	98,000	-2,000	95,000	-5,000
06-SC-01 12 GeV CEBAF Upgrade	25,500	16,500	7,500	-9,000	7,500	-	7,500	-
<b>Total, Construction</b>	<b>80,500</b>	<b>106,500</b>	<b>107,500</b>	<b>+1,000</b>	<b>105,500</b>	<b>-2,000</b>	<b>102,500</b>	<b>-5,000</b>
<b>Total, Nuclear Physics</b>	<b>569,138</b>	<b>595,500</b>	<b>624,600</b>	<b>+29,100</b>	<b>616,165</b>	<b>-8,435</b>	<b>591,500</b>	<b>-33,100</b>



# Other DOE/NP News

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- Adena Walker has joined NP as Program Assistant
- Brian Knesel has joined NP as Financial Management Specialist
- NP has additional active considerations ongoing in the Isotope and SBIR programs
- NP has a continuing need for program managers in Nuclear Structure/Fundamental Symmetries; HI; PRD Division Director
- GRETA has received CD0
- SIPF has received CD0
- First meeting of the Nuclear Data Advisory Committee is upcoming
- Workshop Report, *“Nuclear Data Needs and Capabilities for Applications”* in final preparation
- NP leading a discussion focused on establishing a pan-Federal communication/coordination forum on Nuclear Data
- ASCR-NP Computing Needs Workshop in discussion for June 2016
- PRD Deadline for proposals seeking FY16 funding is December 31, 2015.



# Outlook

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- There is a wealth of science opportunity near term at ATLAS, and longer term at FRIB which will be world leading. It is not too soon to begin to position the low energy community to take full advantage of FRIB as soon as it becomes operational.
- The CEBAF and RHIC programs 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.
- 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
- An equally high priority for the NP community is increasing investment in research and projects as a percentage of the total NP budget. This will have to be accomplished while still respecting the unitarily limit.
- 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 NSACI Strategic Plans

