Office of Nuclear Physics Overview

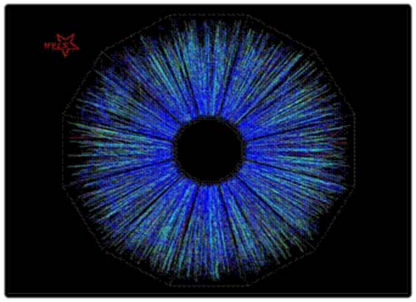
NSAC Meeting

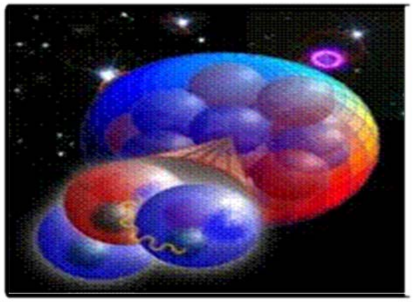
March 23, 2016

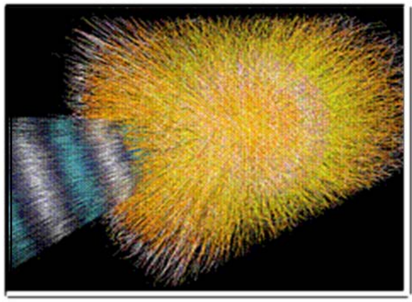
Dr. T. J. Hallman

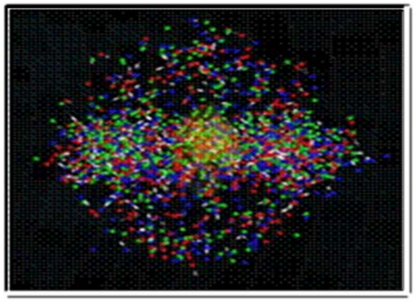
Associate Director for Nuclear Physics

DOE Office of Science







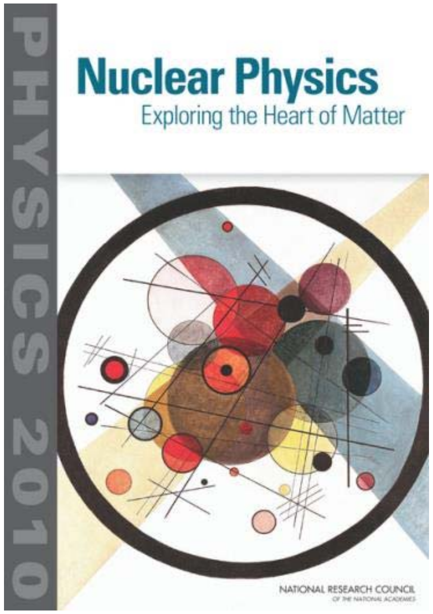


DOE is the Primary Federal Steward of U.S. Nuclear Science

DOE works closely with the community to ensure:

Effective Strategic Planning and Funding

- Identify the scientific opportunities for discoveries and advancements
- Build and operate forefront facilities to address these opportunities
- Develop and support a research community that delivers significant outcomes
- Work with other agencies/countries to optimize use of U.S. resources



Goals

- **World-class facility research capabilities**
  - to make significant discoveries/advancements
- **A strong, sustainable research community**
  - to deliver significant outcomes
- **Forefront advanced technologies, capabilities**
  - for next-generation capabilities
- **A well-managed and staffed, strategic sustainable program**
  - that ensures leadership/optimizes resources

Deliverables

- New insights and advancements in the fundamental nature of matter and energy
- New and accumulated knowledge, developed and cutting-edge technologies, and a highly-trained next-generation workforce that will underpin the Nation's nuclear-related endeavors
- Isotopes for basic and applied sciences

FY2016: DOE NP Appropriation: $617.1M FY 2017 Request: $638.7

The Nuclear Physics Program Stewarded by DOE NP

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

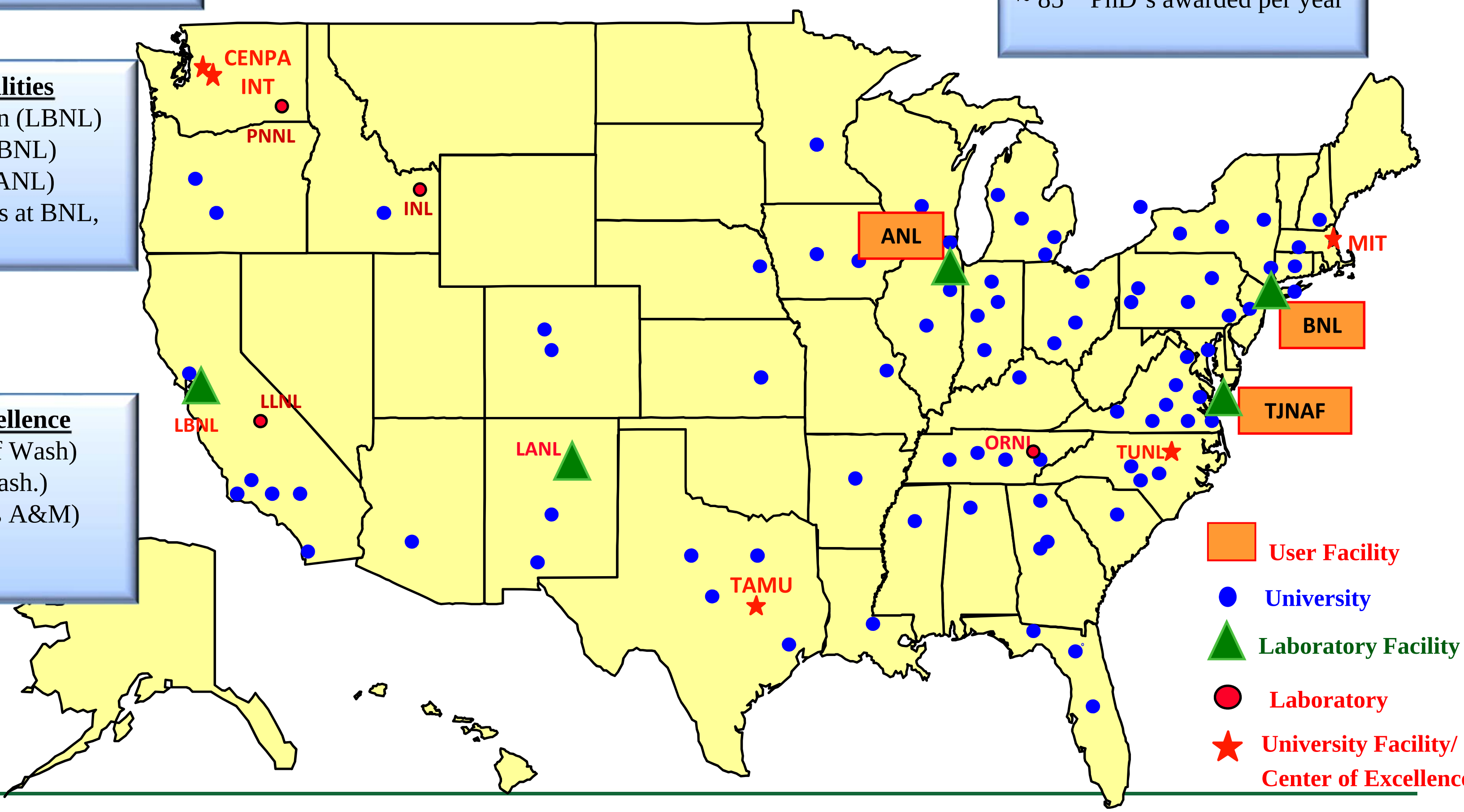
Research Groups
- 9 National Laboratories
- 90 Universities

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)



Report Card on DOE NP Stewardship

2007 LRP Recommendations:

- We recommend completion of the 12 GeV CEBAF Upgrade at Jefferson Lab. The Upgrade will enable new insights into the structure of the nucleon, the transition between the hadronic and quark/gluon descriptions of nuclei, and the nature of confinement.

  Over 96% complete; restart of science in FY2017

- We recommend construction of the Facility for Rare Isotope Beams (FRIB), a world-leading facility for the study of nuclear structure, reactions, and astrophysics. Experiments with the new isotopes produced at FRIB will lead to a comprehensive description of nuclei, elucidate the origin of the elements in the cosmos, provide an understanding of matter in the crust of neutron stars, and establish the scientific foundation for innovative applications of nuclear science to society.

  Construction ~60% complete, 10.5 weeks ahead of schedule

- We recommend a targeted program of experiments to investigate neutrino properties and fundamental symmetries. These experiments aim to discover the nature of the neutrino, yet-unseen violations of time-reversal symmetry, and other key ingredients of the New Standard Model of fundamental interactions. Construction of a Deep Underground Science and Engineering Laboratory is vital to U.S. leadership in core aspects of this initiative.

  Projects underway (KATRIN, CUORE, Majorana Demonstrator, FNPB, neutron EDM)

- The experiments at the Relativistic Heavy Ion Collider have discovered a new state of matter at extreme temperature and density—a quark-gluon plasma that exhibits unexpected, almost perfect liquid dynamical behavior. We recommend implementation of the RHIC II luminosity upgrade, together with detector improvements, to determine the properties of this new state of matter.

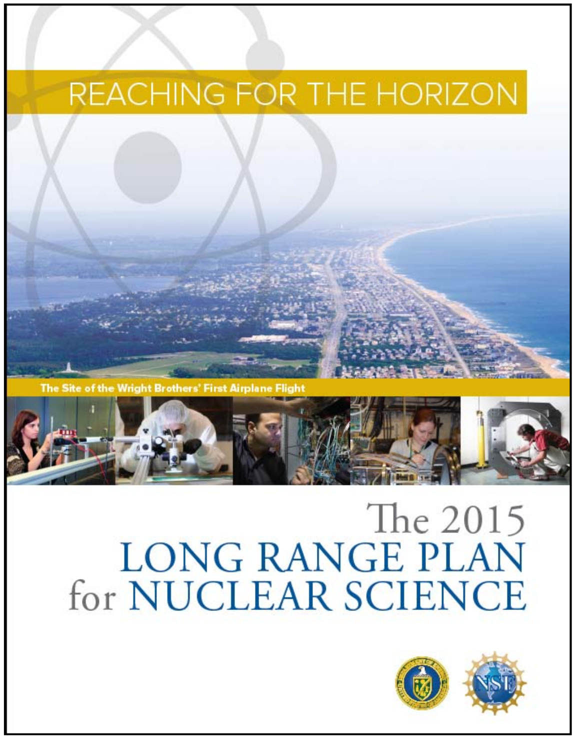
  Upgrade completed

The 2015 Long Range Plan for Nuclear Science

NSAC and APS DNP partnered to tap the full intellectual capital of the U.S. nuclear science community in identifying exciting, compelling, science opportunities

Recommendations:

- The progress achieved under the guidance of the 2007 Long Range Plan has reinforced U.S. world leadership in nuclear science. ***The highest priority in this 2015 Plan is to capitalize on the investments made.***
- The observation of neutrinoless double beta decay in nuclei would…have profound implications.. ***We recommend the timely development and deployment of a U.S.-led ton-scale neutrinoless double beta decay experiment.***
- Gluons…generate nearly all of the visible mass in the universe. Despite their importance, fundamental questions remain…. These can only be answered with a powerful new electron ion collider (EIC). ***We recommend a high-energy high-luminosity polarized EIC as the highest priority for new facility construction following the completion of FRIB.***
- ***We recommend increasing investment in small-scale and mid-scale projects and initiatives that enable forefront research at universities and laboratories.***



NP is implementing these recommendations which are supported in the President's FY 2017 request

Positioning the Field to Pursue the 2015 LRP Vision

2014

Neutrino-less Double Beta Decay Charge Letter (December 2013 (466KB))

Neutrinoless Double Beta Decay Report (April 24, 2014 (1.6MB))

Neutrinoless Double Beta Decay Report Transmittal Letter (May 6, 2014 (63KB))

2015

Neutrinoless Double Beta Decay (NLDBD) Charge Letter (March 30, 2015 (395KB))

Report to NSAC on Neutrinoless Double Beta Decay (November 18, 2015 (1.3MB))

Letter of Transmittal (November 23, 2015 (118KB))

Active Discussion: Cross Agency Management Plan between the National Science Foundation and the Department of Energy, Office of Nuclear Physics, for selecting and funding research and development of technologies aimed at demonstrating the down-selection criteria for the next generation of experiments to observe neutrinoless double beta decay.

MIEs: GRETA and SIPF included in the FY 2017 President's Request

Next Formal Step on the EIC Science Case

THE NATIONAL ACADEMIES OF SCIENCES, ENGINEERING, AND MEDICINE
Division on Engineering and Physical Science
Board on Physics and Astronomy
U.S.-Based Electron Ion Collider Science Assessment

Summary
The National Academies of Sciences, Engineering, and Medicine ("National Academies") will form a committee to carry out a thorough, independent assessment of the scientific justification for a U.S. domestic electron ion collider facility. In preparing its report, the committee will address the role that such a facility would play in the future of nuclear science, considering the field broadly, but placing emphasis on its potential scientific impact on quantum chromodynamics. The need for such an accelerator will be addressed in the context of international efforts in this area. Support for the 18-month project in the amount of $540,000 is requested from the Department of Energy.

<u>Mail reviews received; proposal approved for funding in PAMS; PR package in PAMS being processed.</u>

Progress is also being made on a second Joint NAS study on Space Radiation Effects Testing

Seeding the Possibility of a Future Electron Ion Collider

NP Planning for EIC Accelerator R&D

In view of Recommendation III in the 2015 LRP report on the realization of an EIC, NP is fomenting a plan in discussion with EIC stakeholders:

18 months NAS study:	US-BASED ELECTRON ION COLLIDER SCIENCE ASSESSMENT
March - July 2016:	Competitive FOA published this month, proposals due May 2 to select and fund accelerator R&D for Next Generation NP Facilities for 1 year only.
Summer 2016	Conduct an NP community EIC R&D panel (EIC-R&D) Review charged with generating a report as basis for FY17-FY20+ EIC accelerator R&D funding. NP to appoint Chair of the panel
Late Fall 2016:	Use the EIC panel report from the panel to publish a new Accelerator R&D FOA for FY2017 funding.

Funding amount and source for EIC accelerator R&D in FY17 and beyond:

Funding level:	Aiming for $7M, exact amount to be guided by EIC-R&D Review's report
Funding sources:	~$1.9M from NP competitive pot, the rest generated by percentage tax to RHIC and CEBAF Accelerator Operations budgets (~2.6% FY17 president request for each Lab).

R&D for a Possible Future Electron Ion Collider

EIC R&D Panel Review:

Panel Formation: A community panel, similar to Ozaki panel for RIA.

Charge to Panel: Panel to generate a list of EIC accelerator R&D items with relative priority and estimated cost and duration ranges.

> EIC design Concepts: examine current EIC concepts under considerations in the US and identify a risk level (high, medium or low) for realization of each concept,
>
> Technical Feasibility: For each EIC design concept, identify key areas of accelerator technologies that must be demonstrated or advanced significantly in order to realize the technical feasibility of the concept.
>
> Status of EIC R&D to date: Evaluate current state of EIC related accelerator R&D supported by NP competitive R&D funds and by individual NP Labs.
>
> Priority list of R&D: Generate a list of R&D areas for each EIC concept, prioritized (High, Medium, Low) in the context of associated risk and impact of value engineering and technical feasibility.
>
> Cost and Schedule range: Provide an estimate of cost and schedule range associated with each R&D item from the list of R&D above.

R&D Investment, Present and Potential, in Fundamental Symmetries

MAJORANA DEMONSTRATOR Progess

Goal: Demonstrate backgrounds needed for a tonne scale $0\nu\beta\beta$ experiment.

Configuration: 44-kg of Ge detectors, in two independent cryostats

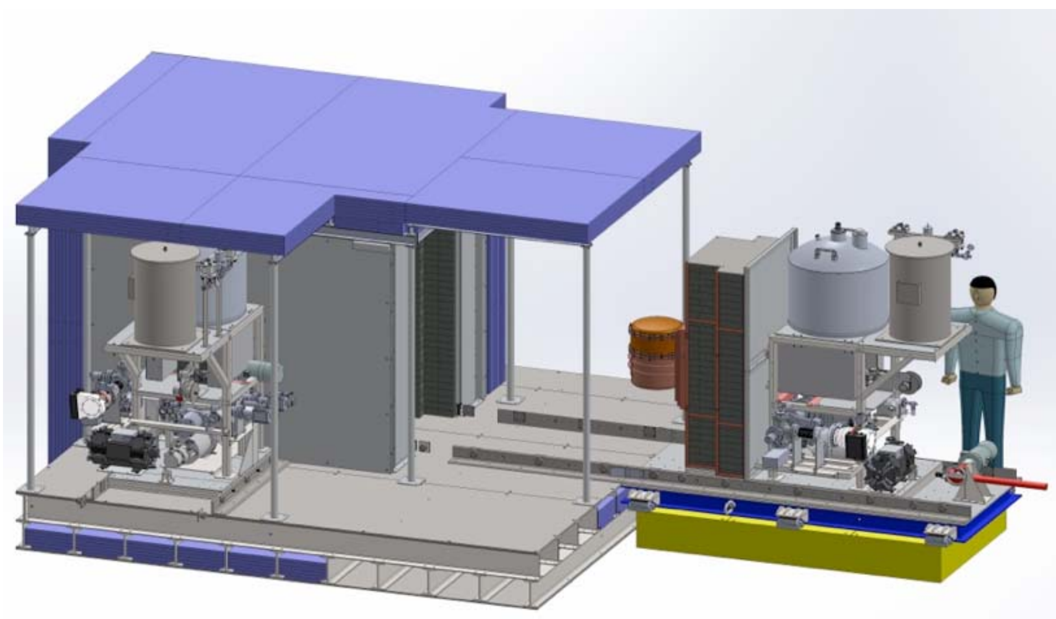
29 kg of 87% enriched ^{76}Ge crystals; 15 kg of ^{nat}Ge, P-type point-contact detectors

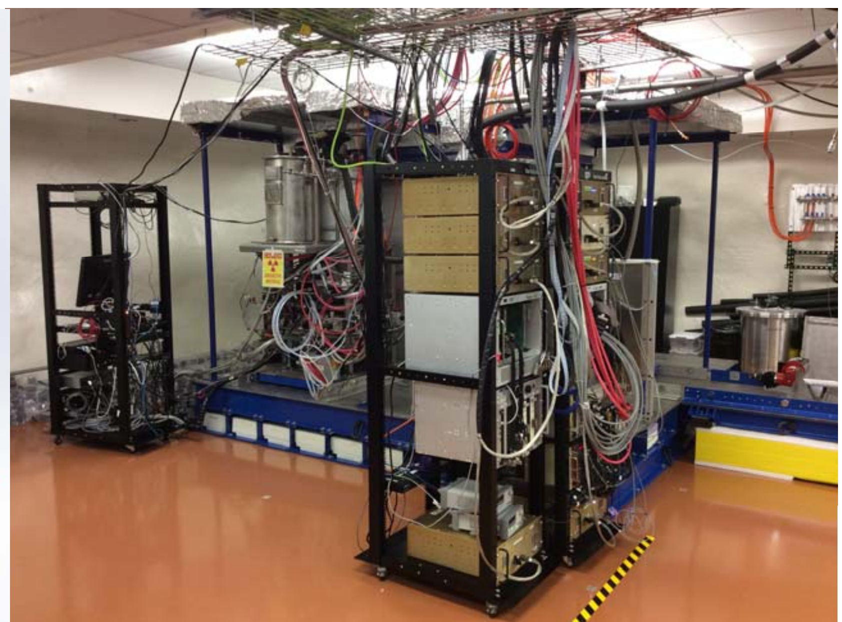
Module One: Installed in-shield and taking low background data since January 2016.

End-to-end analysis underway from July - Oct. 2015 dataset to shake down data cleaning and analysis tools (relatively insensitive because of partial shielding) .

Expect to have first background information from 2016 run in the spring.

Module Two: construction and assembly proceeding on schedule, in-shield commissioning beginning ~ May 2016



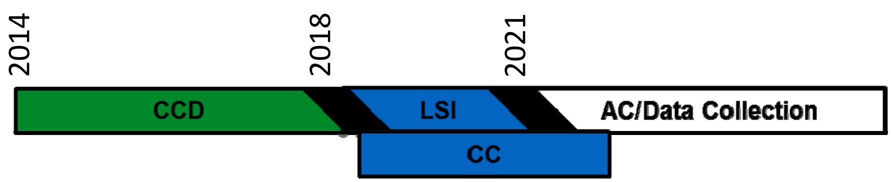


Progress on nEDM at the Spallation Neutron Source

- Completed half of 4-year Critical Component Demonstration (CCD) program

  Goal: reduce technical risk by demonstrating full-scale modules at operating conditions

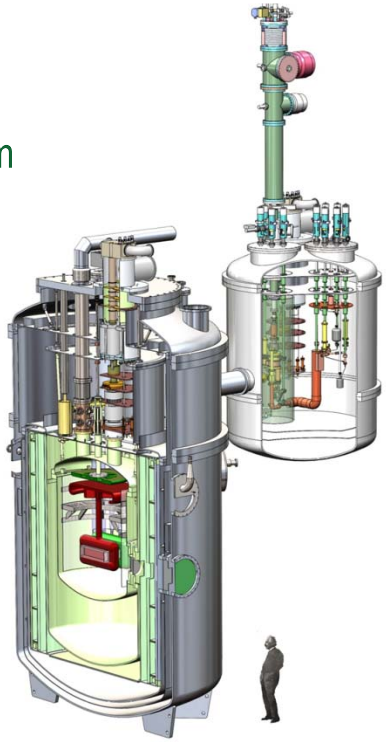
  - High-power non-magnetic dilution refrigerator
  - Polarized Helium-3 (co-magnetometer) injection/transport
  - Magnet coil package
  - High-voltage
  - Ultracold neutron storage
  - Light collection system

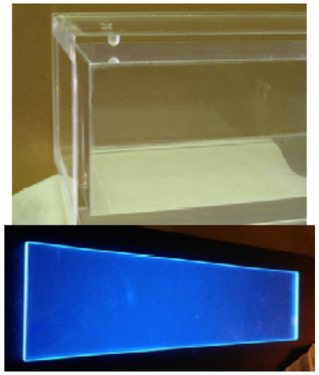


- To be followed by Large Subsystem Integration (LSI) (assembling the modules into a complete experiment) and Conventional Component Procurements (CC)

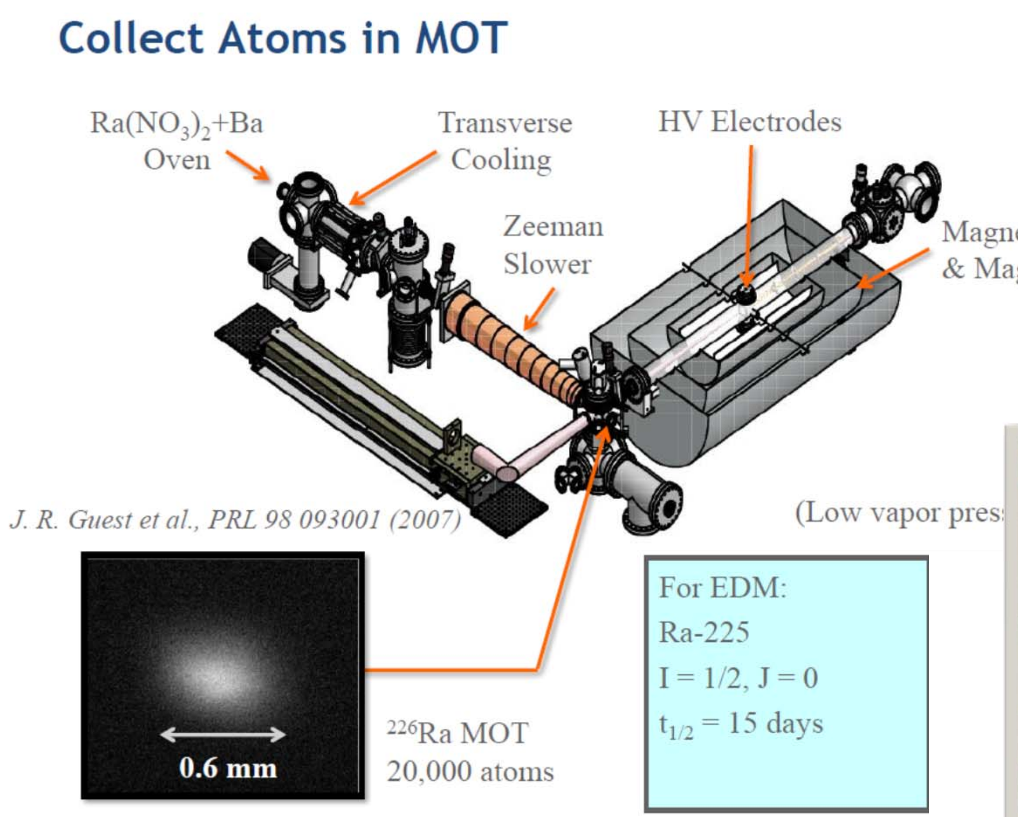
Progress on nEDM at the Spallation Neutron Source

- Alternatives analysis identified changes to experimental design that greatly improve cryogenic maintenance and operation
- Copper-implanted acrylic electrodes (100 cm^2) held > 85 kv/cm in liquid helium at 0.5K
- Minimum goals met for optical signal detection (>8 PE)
- Ultracold neutron wall loss time > 800 s in full-scale acrylic cell
- Required field uniformity demonstrated in ½-scale cryogenic magnet prototype
- Magnetic field monitor proof-of-principle developed
- Dilution refrigerator testbed established





^{225}Ra EDM Experiment: New Results

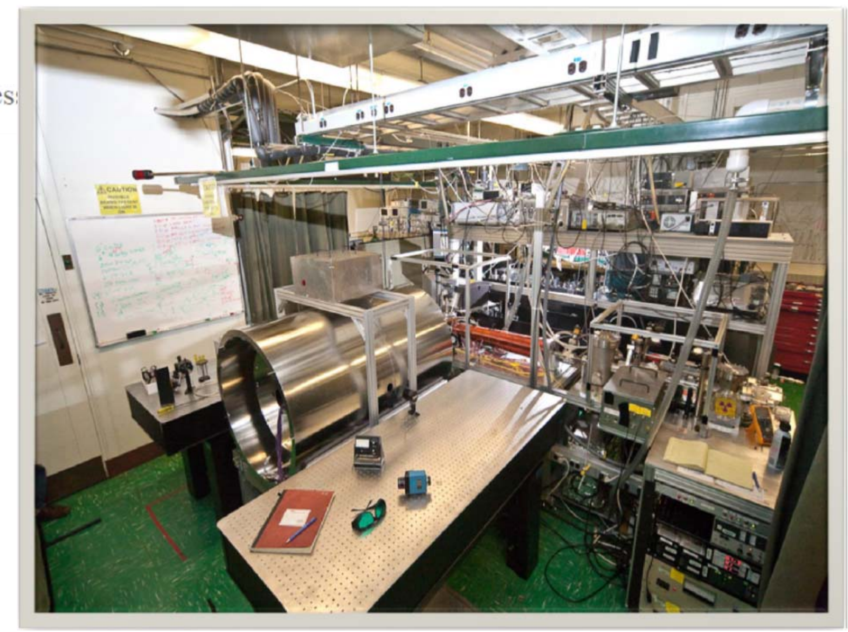


2014: First ^{225}Ra measurement M. Dietrich *et al.*, PRL 114, 233002 (2015)

2015: Updated measurement: factor of 35 improvement

$|d| < 1.4 \times 10^{-24}$ e cm

M. Bishof *et al.*, in preparation



ANL, MSU, USTC and Kentucky

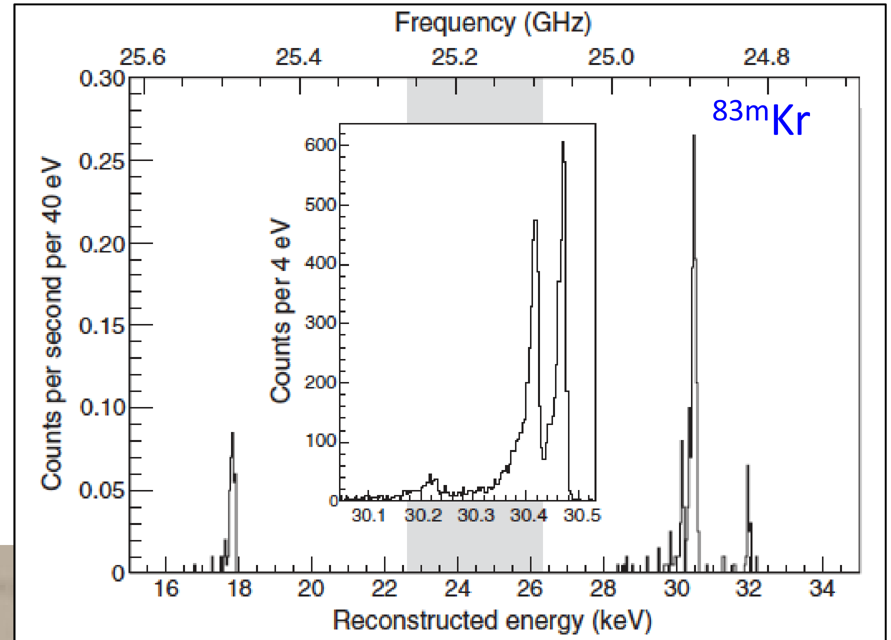
PROJECT 8

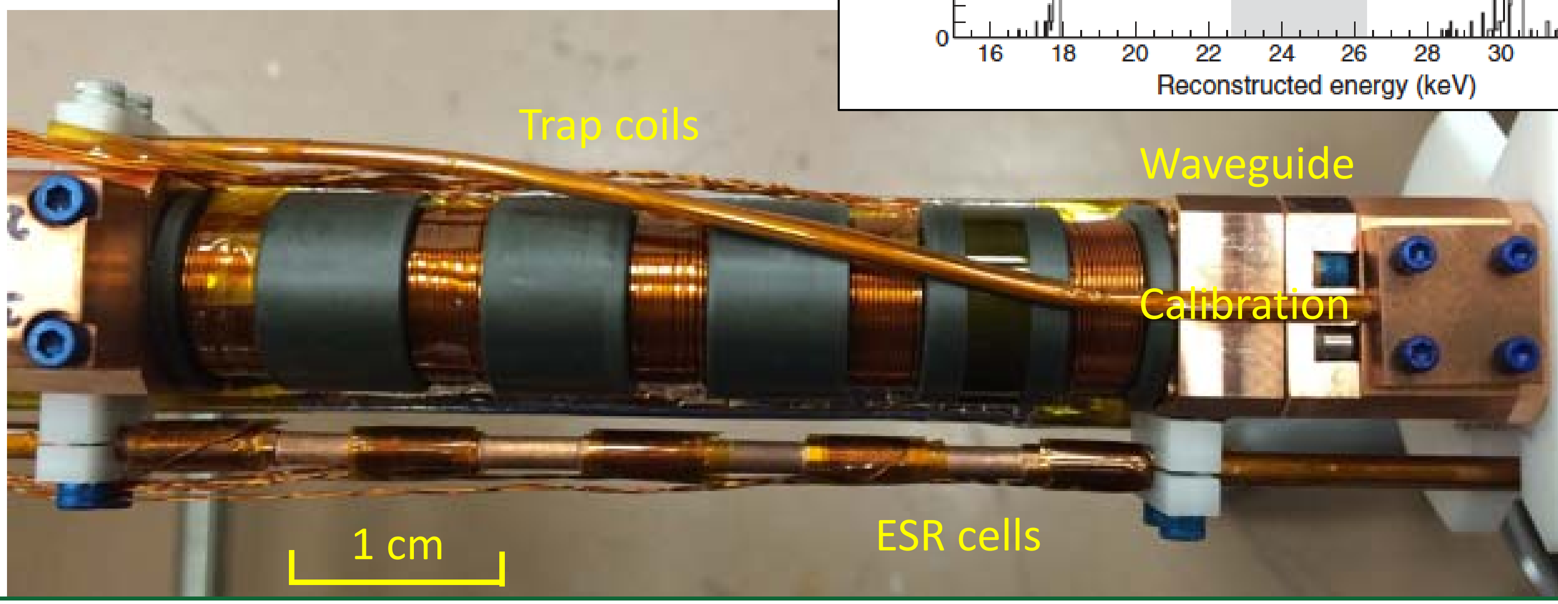
A Potential Major Advance On Measuring m_ν

A new concept for direct measurement of neutrino mass by observation of cyclotron radiation in tritium beta decay.

Successful proof of concept with ^{83m}Kr: PRL 114, 162501 (2014).

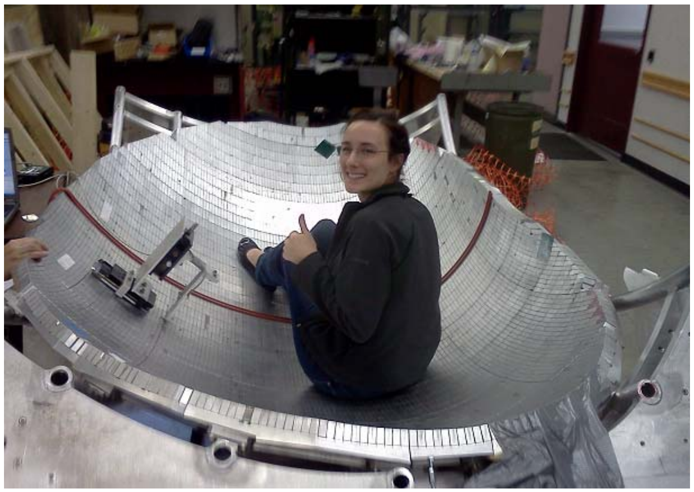
26-GHz tritium cell ready for first data – larger systems to follow.



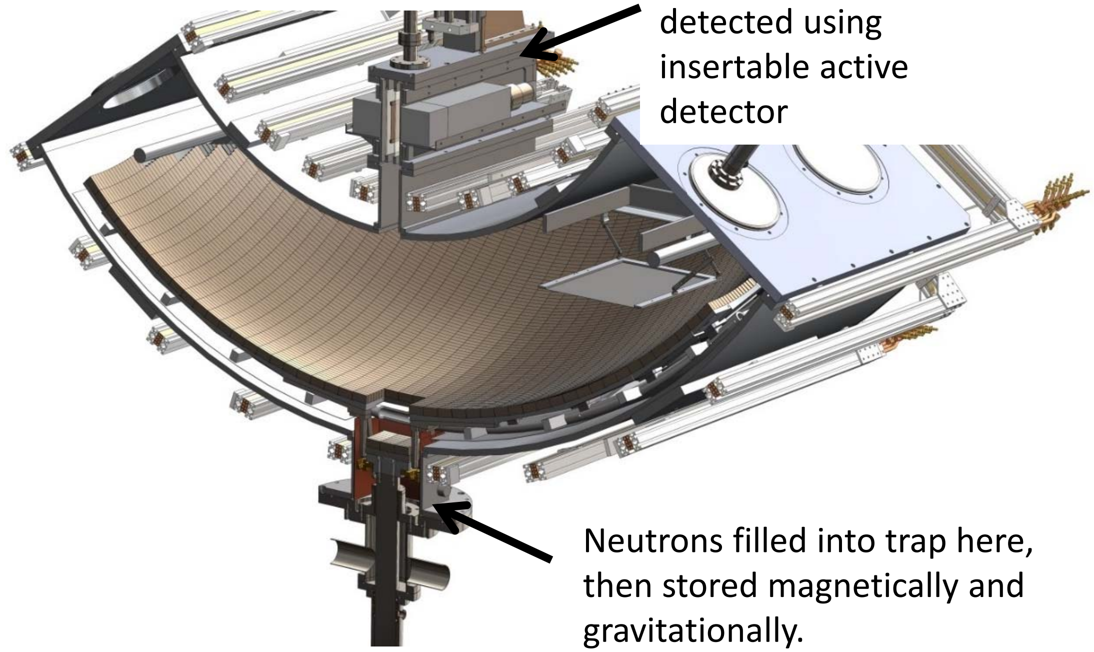


Feasibility Study for a Neutron Lifetime Experiment

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

Progress in 2015-2016 LANSCE run cycle: commissioned an active in situ detector; performed intensive studies of neutron phase space evolution, superbarrier UCN removal ("cleaning"), normalization, and detector efficiency effects.

Committee of Visitors, March 2-4, 2016

For both DOE laboratory and university programs and projects

- Provide an assessment of the processes used to solicit, review, recommend, and document proposal actions and monitor active projects and programs

Within the boundaries defined by DOE missions and available funding

- Consider and provide an evaluation of the following major elements:
  a) The efficacy and quality of the processes used to solicit review, recommend, monitor, and document applications, proposals, and award actions; and
  b) The quality of the resulting portfolio, including its breadth and depth, and its national and international standing.

Comment on:

- observed strengths or deficiencies in any component or sub-component of the Office's portfolio and opportunities for improvements
- progress made towards addressing action items from the previous COV Review.

NP looks forward to the COV Report at the next NSAC Meeting

Nuclear Physics – Research

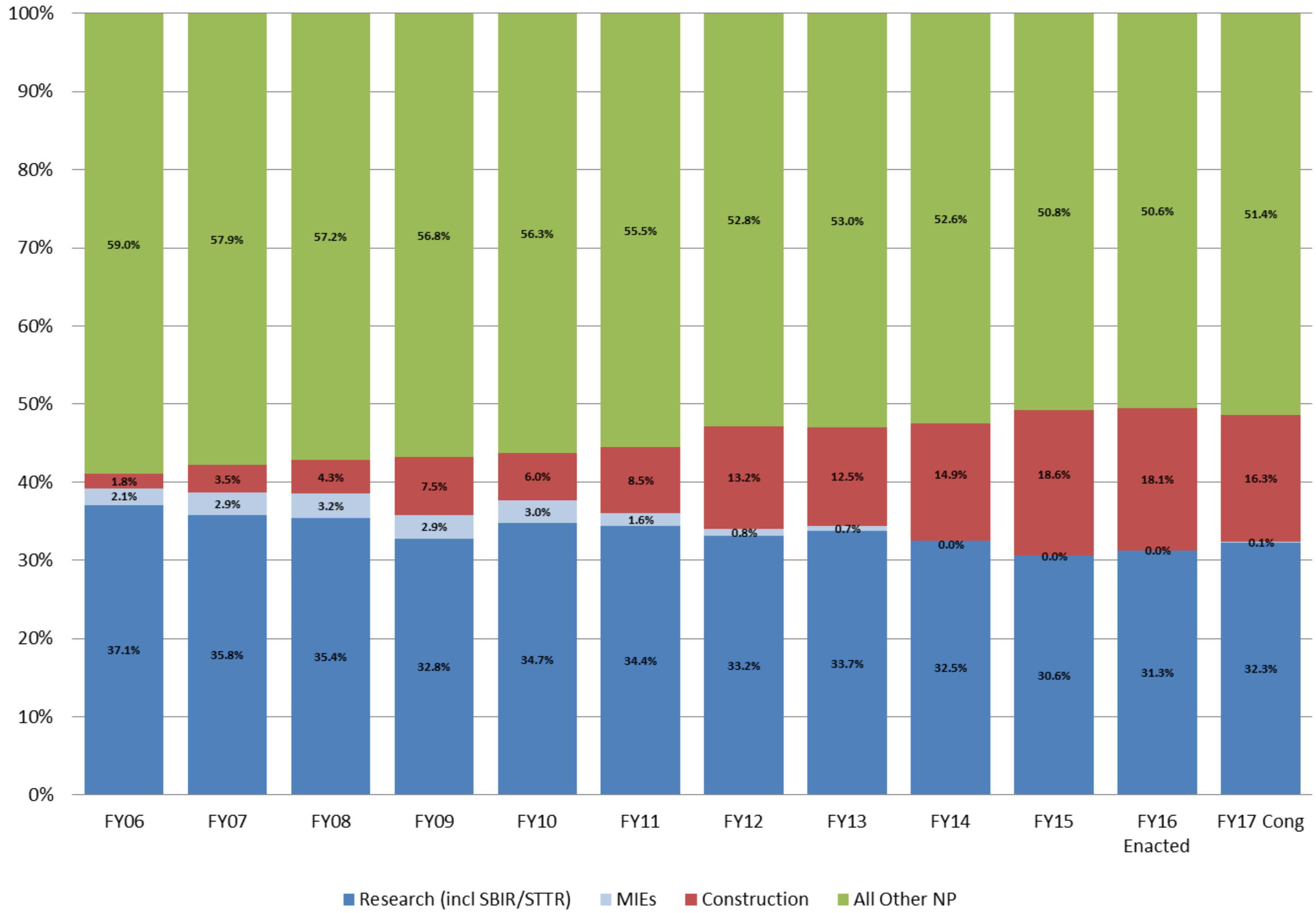
	FY 2016 Enacted	FY 2017 Request	FY17 vs. FY16
Medium Energy	37,802	40,017	+2,215
Heavy Ions	35,822	36,431	+609
Low Energy	51,383	53,894	+2,511
Theory	45,775	46,465	+690
Isotope Program	6,033	10,344	+4,311
Total	**176,815**	**187,151**	**+10,336**

The FY 2017 Request reflects a continued strong commitment to research, which has been constrained during construction of two major facilities.

- **Medium Energy**: Implement the 12 GeV physics research program to advance understanding of strongly interacting matter and search for evidence of new physics beyond the Standard Model; determine the origin of the spin of the proton.
- **Heavy Ions**: Explore newly discovered phenomena in quark gluon plasma formation at RHIC and the LHC, and elucidate broader intellectual connections and impacts in other fields of science.
- **Low Energy**: Develop and implement instrumentation to advance knowledge in nuclear structure and astrophysics at ATLAS and FRIB; carry out research in fundamental symmetries and neutrons, including R&D towards a ton-scale experiment to determine if the neutrino is its own antiparticle.
- **Theory**: Support theoretical research to advance knowledge across nuclear science; expand a collaborative theory effort on FRIB science, as well as continue the new cohort of Topical Theory Collaborations initiated in FY 2016.
- **Isotope Program**: Increase R&D investments to enable innovative approaches to produce and process critical isotopes, including R&D on production of alpha-emitters for clinical trials with the potential to revolutionize treatment of metastasized cancers. Initiate a graduate traineeship in radiochemistry and nuclear chemistry with an emphasis in isotope production and processing.

Funding Trends Within the NP Portfolio

Constructing 2 major facilities has stressed the NP program –
Research trend is beginning to reverse starting in FY 2016 and continuing in FY 2017



Nuclear Physics – Facility Operations

	FY 2016 Enacted	FY 2017 Request	FY17 vs. FY16
Medium Energy (TJNAF Operations)	98,670	104,139	+5,469
Heavy Ions (RHIC Operations)	172,088	179,700	+7,612
Low Energy Operations (ATLAS)	27,402	25,499	-1,903
Isotope Program	15,304	16,526	+1,222
Total	**313,464**	**325,864**	**+12,400**

Increased funding in FY 2017 supports NP's national scientific user facilities (CEBAF, RHIC, ATLAS), the isotope production facilities, and other NP facility commitments.

- **Medium Energy**: Ramp up operations of the newly upgraded CEBAF from commissioning to 2,890 hours of scientific operations in FY 2017 (87% of optimal operations), including support for the operations staff, power costs, materials and supplies, and maintenance activities needed to bring this complex scientific user facility back to full operation mode.
- **Heavy Ions**: Operate RHIC for 3,040 hours (74% of optimal operations), an increase of 550 hours above FY 2016, or ~4 weeks, to optimize data taking and realize RHIC science opportunities in exploring the properties of the quark gluon plasma first discovered there; support maintenance and capital equipment efforts deferred in FY 2016.
- **Low Energy**: Operate ATLAS for 5,900 hours (89% of optimal operations) to continue to meet the high demand for this facility, the only operating low energy nuclear science facility in the US, including increased support for mechanical engineering expertise and accelerator target development; operate the 88-Inch Cyclotron at LBNL for nuclear science research and support of the national security space community; ramp down equipment disposition activities at HRIBF (accounts for overall decrease).
- **Isotope Program**: Maintain mission readiness for safe and reliable operations of isotope production and processing facilities at LANL,ORNL and BNL, and initiate support for operations of the stable isotope enrichment prototype at ORNL.

Nuclear Physics – Projects

Line Items and MIEs (TEC)	FY 2016 Enacted	FY 2017 Request	FY17 vs. FY16
12 GeV CEBAF Upgrade	7,500	…	-7,500
Facility for Rare Isotope Beams (FRIB)	100,000	100,000	…
Gamma-Ray Energy Tracking Array (GRETA) MIE	…	500	+500
Stable Isotope Production Facility (SIPF) MIE	…	2,500	+2,500
Total	**107,500**	**103,000**	**-4,500**

FY 2017 funding is requested for FRIB and two new MIEs: GRETA and SIPF

- **12 GeV CEBAF Upgrade:** FY 2016 was the final year of TEC funding; project is continuing to work towards completion (CD-4B) by the end of FY 2017.
- **FRIB**: FY 2017 funding supports the completion of key conventional construction items, such as the high bay, linac support area, and cryoplant area; work is started on the cryogenics plant and distribution system; fabrication, and assembly efforts continue on technical systems.

  DOE TPC=$635.5M; MSU Cost Share=$94.5M; Total project cost=$730M. Completion (CD-4) by 3Q FY 2022.
- **GRETA**: The Gamma-Ray Energy Tracking Array (GRETA) MIE, a high resolution gamma array tracking device for FRIB, is initiated. The FY 2017 Request of $500,000 supports engineering design and long lead procurement
- **SIPF**: The Stable Isotope Production Facility (SIPF) MIE is initiated to provide a cost-effective domestic capability for production of enriched stable isotopes. Many stable isotope supplies are depleted from the national inventory and are needed for important research and security applications. SIPF will help mitigate dependence of the US on foreign suppliers.

Nuclear Physics
FY 2017 President's Request – Summary

($ in 000s)	FY 2015 Actual	FY 2016 Enacted	FY 2017 Request	FY 2017 vs. FY 2016
Research	167,195	176,815	187,151	+10,366
User Facility Operations	280,873	288,957	303,038	+14,081
Other Operations	24,313	24,507	22,826	-1,681
Projects	106,500	107,500	103,000	-4,500
Other	16,619	19,321	19,643	+322
TOTAL NP	**595,500**	**617,100**	**635,658**	**+18,558**

- **Research** – Support university and laboratory research 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, neutrinoless double beta decay, and isotope production and processing techniques.
- **User Facility Operations** – Operate the three Nuclear Physics user facilities by supporting staff, equipment, and materials required for reliable operations for research focused on: advancing the understanding of strongly interacting matter and its description in QCD, and to search for evidence of new physics beyond the Standard Model at CEBAF; characterizing the perfect quark-gluon liquid discovered in collisions of relativistic heavy nuclei at RHIC; and advancing the areas of nuclear structure and reactions, low-energy tests of the standard model, and nuclear astrophysics at ATLAS.
- **Other Operations** – Maintain mission readiness of the Isotope Program facilities for the production of radioisotopes; continue operations of the 88-Inch Cyclotron at LBNL, and complete disposition activities for HRIBF at ORNL.
- **Projects** – Continue FRIB construction according to its baselined profile, and initiate two MIEs – GRETA and SIPF.
- **Other** – Provide required funding for the SBIR/STTR programs consistent with the legislative mandate (offset partially by transfer of WCF to SCPD).

Office of Nuclear Physics

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Associate Director's Office Staff
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- Brian Knesel, Financial Management Specialist
- Adena Walker, Program Assistant (OA) (Grants)
- Brenda May, Program Analyst
- *Gulshan Rai Technical Advisor*

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Christine Izzo, Program Support Specialist

- Medium Energy Nuclear Physics — Gulshan Rai
- Heavy Ion Nuclear Physics — *James Sowinski (A)*
- **Low Energy Nuclear Physics** — ***Ted Barnes, (A)***
- Nuclear Theory — George Fai
- Nuclear Data and Nuclear Theory Computing — Ted Barnes
- **Fundamental Symmetries** — ***Ted Barnes, (A)***

Facilities & Project Management Division
Jehanne Gillo, Director
Cassie Dukes, Program Support Specialist
Luisa Romero, Isotope Program Analyst

- Nuclear Physics Facilities — *Jehanne Gillo (A)*, James Sowinski
- Nuclear Physics Instrumentation — Elizabeth Bartosz
- Advanced Technology R & D — Manouchehr Farkhondeh
- Nuclear Physics Major Initiatives — James Hawkins
- Industrial Concepts — Michelle Shinn
- Isotope Program Operations — Marc Garland
- Isotope R&D — Dennis Phillips
- Stable Isotopes and Accountable Material — Joel Grimm
- Isotope Facilities — Ethan Balkin
- Isotope Initiatives — Joseph Glaser

(A) - Acting

February 2016

Thank You Don Geesaman !!

Don Geesaman was sworn in as the Chair of NSAC on March 9, 2012 and that was his first meeting as Chair.

Today's meeting is the twelfth he has chaired.

During his terms as Chair he received 11 charges and has overseen the creation and publication of 10 reports, including an implementation plan in FY 2013 and a LRP in 2015, with one report currently in preparation.

His position as NSAC Chair was extended in 2015 by one year, so that he could conduct the exercise leading to the 2015 Long Range Plan for Nuclear Physics, *Reaching for the Horizon*. He has participated in two Committee of Visitor reviews.

Don has contributed <u>extraordinary</u> service to Nuclear Physics and we are all in his debt

Outlook

- There is a wealth of science opportunity near term at ATLAS and NSCL, 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.

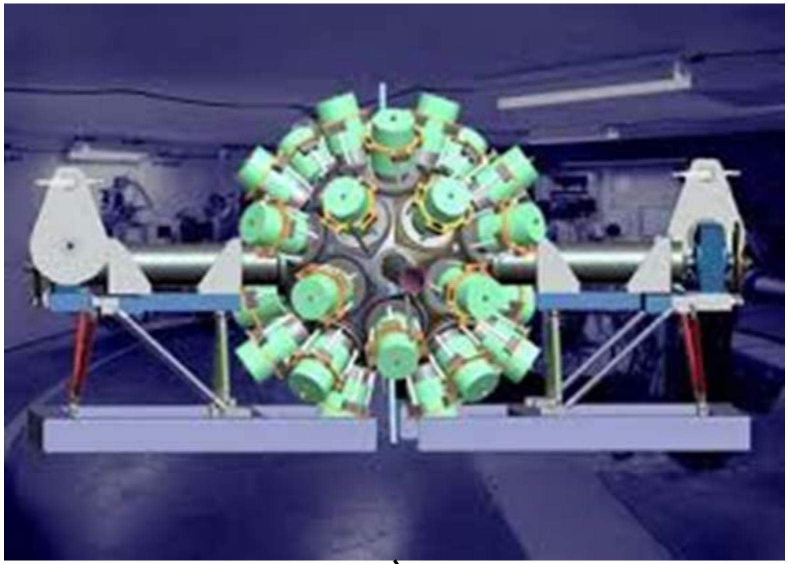
- A very high priority for the community is advancing investment in fundamental symmetries and in particular, ensuring U.S. leadership in the science of neutrino-less double beta decay.
  - A specific challenge will be ensuring essential R&D for candidate technologies is completed in the next 2-3 years prior to a down-select for a ton-scale experiment

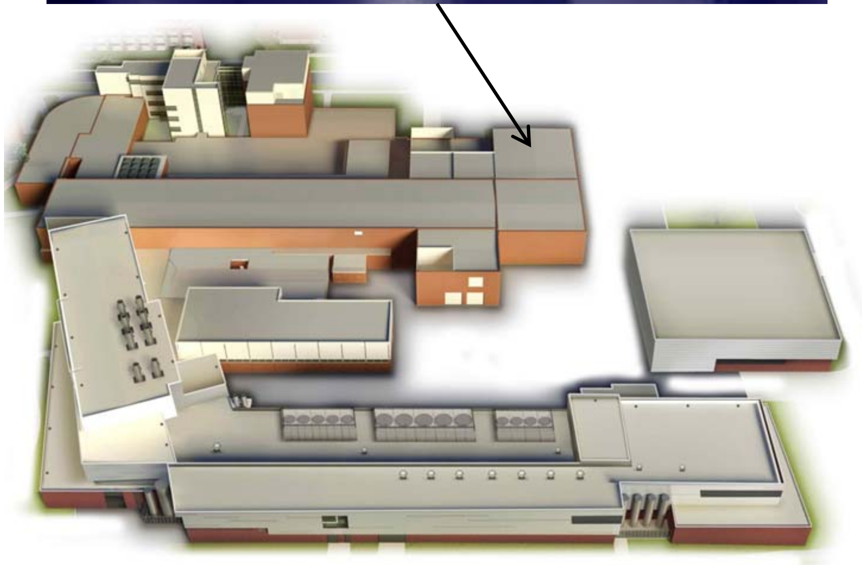
- An equally high priority for the community is increasing investment in research and projects. This will have to be accomplished while still respecting the unitarily limit.

Additional Information

Small and Mid-Scale Projects: Gamma-Ray Energy Tracking Array (GRETA)

- The Request initiates the GRETA Major Item of Equipment (MIE), a premiere gamma-ray tracking device that will exploit world-leading 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 provide world-unique opportunities to advance the rare-isotope science at FRIB and investigate reactions of critical importance for nuclear structure and nuclear astrophysics.





FY 2017 Request: $500,000
Estimated Total Project Cost: $52M-$67M

Small and Mid-Scale Projects: Stable Isotope Production Facility (SIPF)

- The Request initiates the SIPF MIE, which 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.
  - 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.

FY 2017 Request: $2,500,000
Estimated Total Project Cost: $9.5M-$10.5M
Estimated time frame for completion: FY 2020

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.”