Perspectives from the DOE
Office of Nuclear Physics

Presented to the Nuclear Science Advisory Committee
March 9, 2012

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

Discovering, exploring, and understanding all forms of nuclear matter

The Scientific Challenges:
Understand:
- 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 neutrinos and neutrons and their role in the matter-antimatter asymmetry of the universe

FY 2013 Highlights:
- Operations and research at three national nuclear science user facilities (RHIC, CEBAF, ATLAS).
- 12 GeV CEBAF Upgrade to study systems of quarks and gluons and the force that creates protons and neutrons.
- Continued preparation for construction of the Facility for Rare Isotope Beams to study the limits of nuclear existence.
- Research, development, and production of stable and radioactive isotopes for science, medicine, industry, and national security.
- New strategic planning activity begins in FY 2012.
### Office of Science FY 2013 Congressional Request

#### Advanced Scientific Computing Research

<table>
<thead>
<tr>
<th></th>
<th>FY 2011 Current</th>
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<td>410,317</td>
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#### Basic Energy Sciences

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<td>1,638,511</td>
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<td>1,799,592</td>
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#### Biological and Environmental Research

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<td>595,246</td>
<td>609,557</td>
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#### Fusion Energy Sciences

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#### High Energy Physics

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#### Nuclear Physics

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<th></th>
<th>FY 2011 Current</th>
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<th>$</th>
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<tbody>
<tr>
<td></td>
<td>527,684</td>
<td>547,387</td>
<td>526,938</td>
<td>-20,449</td>
<td>-3.7%</td>
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### Workforce Development for Teachers and Scientists

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<thead>
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<td>Science Program Direction</td>
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<tr>
<td>SBIR/STTR (SC funding)</td>
<td>108,418</td>
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<td>—</td>
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<td>Subtotal, Office of Science</td>
<td>4,857,665</td>
<td>4,873,634</td>
<td>5,001,156</td>
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<tr>
<td>SBIR/STTR (Other DOE funding)</td>
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<td>Use of prior year balances</td>
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<td>Total, Science Appropriation</td>
<td>4,897,283</td>
<td>4,873,634</td>
<td>4,992,052</td>
<td>$118,418</td>
<td>+2.4%</td>
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NP has Five Subprograms

- **Medium Energy (TJNAF 12 GeV Energy Upgrade)**
  - Studies the force which binds quarks and gluons in protons and neutrons
  - Searches for Parity violating processes relevant to the New Standard Model

- **Heavy Ion (RHIC and Heavy Ion Research at the LHC)**
  - Investigates the properties of new states of matter with ~100 higher energy density than “normal” nuclear matter
  - Studies the origin of the spin structure of the proton

- **Low Energy (ATLAS and FRIB)**
  - Studies nuclear structure and nuclear astrophysics
  - Investigates the properties of neutrinos, and uses cold neutrons and nuclei to test the Standard Model

- **Theory**
  - Explores all three frontiers of nuclear physics
  - Encompasses the Nuclear Data Program

- **Isotope Production and Applications**
  - Produces, prepares, and distributes isotopes for commercial applications and research
  - Research and development relevant to isotope production
## Nuclear Physics – FY 2013 Congressional Request

<table>
<thead>
<tr>
<th></th>
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<tr>
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<td>Construction</td>
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<td>40,572</td>
<td>-$9,428 -18.9%</td>
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<tr>
<td>**Total *</td>
<td><strong>540,114</strong></td>
<td><strong>547,387</strong></td>
<td><strong>526,938</strong></td>
<td><strong>-20,449 -3.7%</strong></td>
</tr>
</tbody>
</table>

* FY 2011 includes SBIR/STTR for comparability
The 12 GeV CEBAF Upgrade at TJNAF is 60% Complete

The 12 GeV CEBAF Upgrade will enable world-leading research on:

- 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

Main Elements of the 12 GeV CEBAF Upgrade

- Add 5 C100 cryomodules
- 20 cryomodules
- Refurbished arc magnets
- New Hall D
- Add arc
- Enhanced capabilities in existing Halls
- Add 5 C100 cryomodules
- 20 cryomodules

A photograph of one of the superconducting radio frequency (SRF) cavities developed and constructed at Thomas Jefferson National Laboratory (TJNAF) to increase the energy of the CEBAF electron beam. There are eight such cavities in each of the ten C100 cryomodules installed as part of the 12 GeV CEBAF Upgrade (above schematic).
12 GeV Upgrade – Highlights

- Hall D – equipment installation in progress
- Two high-gradient 12 GeV cryomodules installed and delivering high quality beam; third moved to tunnel
- CHL-2 compressors/coolers/skids in place

- Superconducting magnets under construction
- All major detector systems under construction
  All 48 Hall D BCAL modules on site (U. Regina)
- Performance Index: schedule 95% ; cost 96%
Impacts of Reduced Funding in FY 2012 Below 12 GeV Project Baseline

Assuming FY 2013 Funding According to the Baselined Project Profile (No Restoration of the FY 2012 Reduction in FY 2013):

- The 12 month shutdown for construction activities is extended to 18 months, eliminating time for machine studies in FY 2013 prior to the restart of operations, increasing the risk to machine operational reliability.
- There is a 6 month to one year delay in the start of data taking and scientific return on investment.
- Reduction of the Project scope eliminates a spare superconducting magnet, increasing the risk of single point failure and a possible extended loss of productivity in new Hall D.
- There is a significant increase in the cost risk and potential increase in the Total Project Cost (TPC).
- There is a significant reduction in the schedule float for two of three experimental halls (B, C), increasing the risk for planned on-time project completion.
- The transition of FTE's from construction to operations without a loss of key staff for efficient experimental operations will be a challenge.

Aerial view of TJNAF Site

Halls, A, B, C

Accelerated Particle Racetrack (underground)

Hall D

Hall D

Nuclear Science Advisory Committee Meeting 03/09/2012
FY2011 Accomplishments at the Relativistic Heavy Ion Collider

- 2011 Nishina Memorial Prize for research on PHENIX Quark-Gluon Plasma studies of thermal di-lepton spectra & early temperatures in RHIC collisions.

- DOE Secretary’s Achievement Honor Award for RHIC-ATLAS Computing Facility team.

- STAR discovery of anti-helium4 published in Nature, highlighted among Discover magazine’s most important science stories of 2011.

- PHENIX & STAR 2005 White Papers surpass 1000 (now 1100) citations each which places them among the 300 most highly cited HENP papers ever!

- 2011 DOE S&T Peer Review of RHIC: “Both experiments (PHENIX and STAR) have been extraordinarily successful in generating interesting and even spectacular new physics results from their experiments at RHIC. Both experiments have demonstrated originality and creativity, enhancing the detector performance, utilizing improved luminosity, and creating new physics insights.”
Heaviest Anti-Nucleus Ever Observed Discovered at RHIC

The graph below shows particle counts by mass, showing ordinary helium nuclei (He-3 and He-4) in orange, and their antimatter counterparts (antihelium-3 and antihelium-4) in blue. The newly discovered antimatter nuclei, antihelium-4, are cleanly separated from the lighter isotopes, and are at the correct mass.

This discovery (Nature 473 (2011) 353) shows that complex anti-nuclei will form if enough anti-protons and anti-neutrons are present.

It underscores a grand challenge question of modern science: what process in the early universe resulted in more matter than anti-matter being present today?

**Third in the Discover Magazine Top Ten Physics and Math Stories for 2011: “Helium’s Anti-Matter Twin Created”**

Against one in 28 billion odds, two anti-protons and two anti-neutrons combine in RHIC collisions to form anti-helium 4, the heaviest anti-nucleus ever observed.
Impacts of Reduced Funding in FY 2013 for RHIC Operations and Research

- University and laboratory research is reduced 5.8% relative to FY 2012 and will focus on the highest priority experiments at RHIC.

- Reduced funding will support an estimated 1,360 hours of operations for the highest priority experiments. This is a decrease of 1,030 hours relative to FY 2012.

- Effective operation will be achieved by combining FY 2013-FY 2014 running into a single back-to-back run bridging the two fiscal years. BNL and DOE are currently assessing what funding could be redirected into operations on a one-time emergency basis to increase running time.

- Impacts of constrained FY 2012 funding, including a voluntary reduction in force at RHIC and one-time cuts to materials and supplies, are still being assessed and may further impact FY 2013 levels of operations.

- Decrease for lab-wide General Purpose Equipment at BNL.

Above: Side view of Monte Carlo Simulation of Perfect Liquid produced in head-on collisions of gold nuclei at RHIC. Bottom: Head on view of measured pattern of sub-atomic particles emitted in RHIC collisions.

There are presently ~ 700 FTE supported by NP at BNL for RHIC operations and research activities.
First Heavy Ion Results at LHC Confirm A New State of Matter is Produced in Relativistic Nucleus-Nucleus Collisions

Heavy ion data at the LHC indicate a new state of opaque, strongly interacting matter similar to that first discovered at RHIC is produced in heavy ion collisions. “Jets” of energetic particles that traverse the new form of matter are disrupted (right) unlike in proton-proton collisions (left).

The results show that this new form of matter, believed to have influenced the evolution of the early universe, has unique properties and interacts more strongly than any matter previously produced in the laboratory.
Argonne Tandem Linac Accelerator System Layout

ATLAS
A Unique Premier Stable Beam Facility

[Diagram of ATLAS layout with various labeled components such as CARIBU, ECR I and II Ion Source, FN-Tandem Injector, ATLAS Linac, Booster Linac, SC Solenoid/GC-RFQ, Spectrograph/GC-RFQ, Canadian Penning Trap, Atomic Physics, Target Area II, Target Area III, Target Area IV, Helios, GP/Gammasphere Beamline, Split-Pole Spectrometer, Fragment Mass Analyzer, GAMMASPHERE, Hot Lab, Accelerator Control Room, and PII.]
Experimental Support & ATLAS Operations: Statistics

### Reliability

- **92%**

### Mode of Operation

- **7 days/week** to address very high demand by Users

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#### ATLAS PAC Results

- Statistics from the ATLAS Program Advisory Committee (PAC) show a persistent trend which will increase until the start of FRIB
  - high number of proposals
  - oversubscription (the yellow versus the green)

- New science opportunities will be provided in FY2012 enabled by the Californium Rare Isotope Breeder Upgrade (CARIBU)
University and laboratory research is reduced 5.8% relative to FY 2012 and will focus on the highest priority experiments at ATLAS.

ATLAS beam operations are supported for 4,000 hours of operations, 80% of the maximum 5,000 hours possible with the scheduled installation of facility upgrades in FY 2013.

Facility operations funding in FY 2012 and the modest increase in FY 2013 does not keep pace with Cost of Living Increases.

Impacts on workforce of constrained FY 2012 funding and the FY 2013 proposed level of funding are being assessed.

- Statistics from the ATLAS Program Advisory Committee (PAC) show a persistent trend which will increase until the start of FRIB
  - high number of proposals
  - oversubscription (the yellow versus the green)
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 ultimate limits of existence for nuclei
- Nuclei which have neutron skins
- The 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 model of nuclei and how they interact.
The Administration strongly supports the Facility for Rare Isotope Beams (FRIB) at Michigan State University (MSU).

Even in these tight budget times, the President has continued to make FRIB a priority for funding and has requested $22 million in FY 2013 to keep the project moving forward. This is the same amount Congress appropriated for FRIB in FY 2012.

April 24-26, 2012 the project will undergo a planned review by the SC Office of Project Assessment to assess ongoing project activities.

The Office of Science has used the Nuclear Science Advisory Committee to provide regular reviews of Nuclear Physics programs and priorities, most recently in 2007 and 2002.

The Office of Science will ask the NSAC Committee to begin working on its next review this year, but will not charge the committee with making specific recommendations on the future of FRIB or any other specific facility. In terms of timing, in the past, the committee has taken roughly a year-and-a-half to complete the review.

A thin film of liquid lithium ~ 420 µg/cm² thick moves at ~ 70 meters per second from the top to the bottom of the opening. A beam of Uranium Ions will be passed through the film to strip away atomic electrons so that the uranium ions can be accelerated to the full energy of the FRIB.

National Labs Developing Technology for FRIB

Argonne National Laboratory
Brookhaven National Laboratory
Lawrence Berkeley National Laboratory
Oak Ridge National Laboratory
Thomas Jefferson National Laboratory
Stanford National Laboratory
Sandia

~10-15 FTE's out of 115 FTE (155 heads) currently working on the FRIB
Neutrino-less Double Beta Decay

Grand challenge question: Is the neutrino its own anti-particle?

- An R&D effort on the Majorana Demonstrator (MJD) will help establish the feasibility of a tonne-scale $^{76}$Ge neutrino-less double beta-decay experiment.
- The MJD technology demonstration is planned prior to a down-select with the German GERDA experiment between competing Ge technologies and a planned collaboration together.
- MJD is on track with electroforming and with procurement and processing of enriched Ge.
- MJD plans to go underground with natural Ge in a prototype cryostat at the Sanford Laboratory (South Dakota) in about March 2012.
- The technology and the location of a future, international tonne-scale experiment is TBD based on the best value and the best science capability.
## Nuclear Theory

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<td>SciDAC</td>
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<td>0</td>
<td>0</td>
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<td>Nuclear Data</td>
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<td>6,933</td>
<td>-427</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>39,407</strong></td>
<td><strong>37,179</strong></td>
<td><strong>-2,228</strong></td>
<td><strong>-5.7%</strong></td>
</tr>
</tbody>
</table>

- University and national laboratory research is reduced by 5.8% relative to FY 2012.
- Funding for SciDAC activities is held flat with the FY 2012 level.
- Funding for the Nuclear Data program is reduced by 5.8% relative to the FY 2012 level for university and national laboratory research.
An SC-NNSA Joint Workshop on Isotope Supply and Demand
A New Era of Communication and Coordination on Isotopes by Federal Agencies

1st Workshop on Isotope Federal Supply and Demand, Jan 11-12, 2012

- Armed Forces Radiobiology Research Institute
- Central Intelligence Agency
- Defense Threat Reduction Agency
- Department of Agriculture
- DOE/Office of Environmental Management
- DOE/Office of Intelligence
- DOE/New Brunswick Laboratory
- DOE/Nuclear Energy
- DOE/National Nuclear Security Administration
- DOE/Office of Science
- DOE/Savannah River Operations Office
- Department of Health and Human Services
- Department of Homeland Security
- Department of Transportation
- Environmental Protection Agency
- Federal Bureau of Investigation
- National Aeronautics and Space Administration
- National Institutes of Health
- National Institute of Standards and Technology
- National Science Foundation
- National Security Staff
- Office of the Assistant Secretary of Defense
Some key isotopes and radioisotopes and the companies that use them

<table>
<thead>
<tr>
<th>Isotope/Isotope Pair</th>
<th>Application</th>
<th>Company</th>
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<tbody>
<tr>
<td>Strontium-82, Rubidium-82</td>
<td>Imaging / Diagnostic cardiology</td>
<td>NRD</td>
</tr>
<tr>
<td>Germanium-68, Gallium-68</td>
<td>Calibration / PET scan imaging</td>
<td>ISOFLEx</td>
</tr>
<tr>
<td>Californium-252</td>
<td>Oil and gas exploration and manufacturing controls</td>
<td>GE Healthcare</td>
</tr>
<tr>
<td>Selenium-75</td>
<td>Radiography / Quality control</td>
<td>Bracco Diagnostics Inc.</td>
</tr>
<tr>
<td>Actinium-225, Yttrium-90, Rhenium 188</td>
<td>Cancer / Infectious disease treatment</td>
<td>Spectrum Techniques</td>
</tr>
<tr>
<td>Nickel-63</td>
<td>Explosives detection at airports</td>
<td>Schlumberger</td>
</tr>
<tr>
<td>Gadolinium-160, Neodymium-160</td>
<td>Tracers and contrast agents for biological agents</td>
<td>Westinghouse</td>
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<tr>
<td>Iron-57, Barium-135</td>
<td>Standard sources for mass spectroscopy</td>
<td>General Atomics and Affiliated Companies</td>
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<tr>
<td>Sulfur-34</td>
<td>Environmental monitoring</td>
<td>Inorganic Ventures</td>
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<td>Rubidium-87</td>
<td>Atomic frequency / GPS applications</td>
<td>Isotope Products Laboratories</td>
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<td>Sigma Scientific</td>
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<tr>
<td>Samarium-154</td>
<td>Solar energy / transportation applications</td>
<td>Aldrich Chemistry</td>
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Isotopes and Radioisotopes in Short Supply Provided at Full Cost Recovery by the Office of Science to Support U.S. Needs and Industrial Competitiveness
## Isotope Program

<table>
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<th>FY 2012 Approp</th>
<th>FY 2013 Request</th>
<th>FY 2013 to FY 2012 Change $k</th>
<th>%</th>
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<tr>
<td>Research</td>
<td>4,827</td>
<td>4,453</td>
<td>-374</td>
<td>-7.7%</td>
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<tr>
<td>Operations</td>
<td>14,255</td>
<td>14,255</td>
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<td>0</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>19,082</strong></td>
<td><strong>18,708</strong></td>
<td><strong>-374</strong></td>
<td><strong>-2.0%</strong></td>
</tr>
</tbody>
</table>

- University and laboratory research is reduced 5.8% relative to FY 2012.
- Decrease also reflects support in FY 2012 for a one-time R&D effort in support of the development of californium-252 target for the CARIBU upgrade at ATLAS.

- Operations are maintained at the same funding level as FY 2012 for the Isotope Production Facility and Brookhaven Linac Isotope Producer, as well as capabilities at ORNL.
- Funding is maintained for the National Isotope Development Center, a virtual service center which coordinates DOE isotope production across the federal and academic community.
The FY 2013 request for Nuclear Physics optimizes, within available resources, scientific productivity by a balance of investments in research, facility operations, new tools, and capabilities.

- It continues support for the two highest priorities in the 2007 Long Range Plan for Nuclear Science:
  - 12 GeV CEBAF Upgrade
  - Facility for Rare Isotope Beams (FRIB)
- The FY 2013 budget is a decrease of $20.4M, or 3.7%, relative to the enacted FY 2012 appropriation.
  - Funding for research across the program decreases by $9.9M, or 5.8%, relative to FY 2012.
  - NP national user facilities are operated for an estimated 5,360 hours of beam time for research, 38% of optimal utilization for the operating facilities, and a decrease of about 6,800 hours compared with the beam hours planned for FY 2012.
    - Reduction in hours is a result of reduced RHIC and ATLAS operations, and a planned shutdown period at CEBAF associated with the construction of the 12 GeV CEBAF Upgrade.
    - At RHIC, FY 2013-FY 2014 running will be combined into a single back-to-back run bridging the two fiscal years.
    - HRIBF D&D activities are supported.
  - Funding for the 12 GeV CEBAF Upgrade project (TEC and OPC) ramps down $6.9M according to the original baseline plan; it does not restore the FY 2012 reduction of $16M.
  - Funding for FRIB is flat with the FY 2012 enacted level.
  - Funding is provided for the STAR Heavy Flavor Tracker MIE per the project baseline.
This chart reflects the enacted FY 2010-FY 2012 appropriations and the FY 2013 Congressional Request for the Nuclear Physics program.

The black line represents estimated funding needed to implement the majority of elements of the NSAC 2007 Long Range Plan (LRP).
66% of the FY 2013 NP budget supports operations or construction of facilities & instrumentation. The percentage devoted to major projects is 12% in FY 2013.

FY 2013 Congressional Request
Nuclear Physics by Major Category

Major Projects (12 GeV, FRIB) 12%
Facility Operations 52%
Research 31%
Major Items of Equipment 1%
All Other (GPE) 1%
Research (SBIR/STTR) 3%

FY 2013 Congressional Request Total = $526.9M
Timeline of DOE Nuclear Physics Facilities

88-Inch Cyclotron 1962-2003
Bevelac 1971-1993
Bates 1971-2005
LAMPF 1972-1993
ATLAS 1985-Present
LEGS at BNL 1987-2007
AGS HI 1992-98
TJNAF 1994-Present
HRIBF 1996-2011
RHIC 2000-Present

Additional Comments:
Indiana University Cyclotron Facility (begun 1978, closed 2001)
Opportunities passed over due to prioritization in the field are not shown: e.g., KAON, LISS, ORLAND
Running Hours at NP User Facilities

Overall NP Facilities operate at ~38% of optimum utilization in FY 2013

- RHIC Operations – RHIC is supported for 1,360 hours (9-11 weeks) of back-to-back running in FY 2013 and FY 2014
- CEBAF Operations – Planned shutdown during FY 2013 for installation of 12 GeV Upgrade
- ATLAS Operations – Maximum number of hours ATLAS can operate in FY 2013 is 5,000 due to CARIBU upgrade
- HRIBF Operations – Operations as a national user facility cease at the end of March 2012
Conclusion

The FY 2013 President’s request for Nuclear Physics provides resources for:

- U.S. world leadership in discovery science illuminating the properties of nuclear matter in all of its manifestations.

- Tools necessary for scientific and technical advances which will lead to new knowledge, new competencies, and groundbreaking innovation and applications.

- Strategic investments in tools and research to provide the U.S. with premier research capabilities in the world.

- NP continues, and will continue to support a high impact world-class research effort with world leading facilities and research tools.

- Nuclear Physics, similar to all Federally supported programs, is potentially facing very challenging budgets. NP will work with the community to mitigate impacts and ensure continuation of the highest priority, highest impact nuclear science research.
The Breadth of the Horizon for Discovery in Nuclear Science

Evolution of the Universe

- Neutron-rich Nuclei; Structure Of Nuclei;
- Reactions in Core Collapse Super Novae;
- Super-Heavy Element 117 Heavy Nuclei Formation;
- Density Effects in Nuclei;
- Neutron Skins;
- Nuclear-Reactions;

NP Discovery Horizon

- Anti-Helium 4; Proton Spin
- Majorana/DIRAC Neutrino; Perfect QGP Liquid
- Neutron Beta Decay; Neutron EDM; Parity Violation Searches;

- 29
Neutrino mixing angle $\theta_{13}$ is non-zero at 5.2 $\sigma$.

**Observation of $\theta_{13}$**

It takes a “scientific village”…

NP’s contribution: support, along with HEP, of the nuclear chemists’ effort on Gadolinium loaded liquid scintillator and materials compatability characterization.

Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment
Volume 578, Issue 1, 21 July 2007, Pages 329–339

“Gadolinium-loaded liquid scintillator for high-precision measurements of antineutrino oscillations and the mixing angle, $\theta_{13}$”

M. Yeh, A. Garnov, R.L. Hahn

Chemistry Department, Brookhaven National Laboratory,

\[
\sin^2 2\theta_{13} = 0.092 \pm 0.016 \text{(stat)} \pm 0.005 \text{(syst)}
\]

Non-zero $\theta_{13}$ enables a clear path forward towards measuring leptonic CP violation.
Additional Information
Nuclear Physics Program Mission

Mission: To discover, explore and understand all forms of nuclear matter; to understand how the fundamental particles, quarks and gluons, fit together and interact to create different types of matter in the universe, including those no longer found naturally

Priorities:
• To understand how quarks and gluons assemble into the various forms of matter and to search for yet undiscovered forms of matter
• To understand how protons and neutrons combine to form atomic nuclei and how these nuclei have emerged during the 13.7 billion years since the origin of the cosmos
• To understand the fundamental properties of the neutron and develop a better understanding of the neutrino
• To conceive, plan, design, construct, and operate national scientific user facilities; to develop new detector and accelerator technologies
• To provide stewardship of isotope production and technologies to advance important applications, research and tools for the nation
• To foster integration of the research with the work of other organizations in DOE
### Office of Nuclear Physics FY 2013 Congressional Request

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
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<tbody>
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<td><strong>Research</strong></td>
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<td>173,525</td>
<td>172,365</td>
<td>162,432</td>
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<td>RHIC</td>
<td>157,195</td>
<td>159,385</td>
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<td>156,571</td>
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<td>ATLAS</td>
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<td>16,429</td>
<td>+381</td>
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<td>HRIBF</td>
<td>17,080</td>
<td>17,165</td>
<td>6,821</td>
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<td>-6,821</td>
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<td><strong>Total, National User Facilities</strong></td>
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<td>275,309</td>
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<td></td>
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<tr>
<td>Isotope Production Facilities</td>
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<td>88-Inch Cyclotron</td>
<td>4,089</td>
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<tr>
<td>ORELA</td>
<td>164</td>
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<td>164</td>
<td>164</td>
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<td>HRIBF D&amp;D</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>6,479</td>
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<tr>
<td>Homestake De-watering</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>-4,500</td>
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<tr>
<td><strong>Total, Other Facility Operations</strong></td>
<td>20,369</td>
<td>20,363</td>
<td>22,919</td>
<td>24,898</td>
<td>+1,979</td>
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<tr>
<td><strong>Major Items of Equipment (TPC)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>GRETINA</td>
<td>730</td>
<td>...</td>
<td>...</td>
<td>...</td>
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<td>ALICE EMCal</td>
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<td>nEDM</td>
<td>4,500</td>
<td>2,100</td>
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<td>...</td>
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<tr>
<td>CUORE</td>
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<td>800</td>
<td>536</td>
<td>...</td>
<td>-536</td>
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<td>STAR HFT</td>
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<td>3,050</td>
<td>4,400</td>
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<td><strong>Total, MIEs</strong></td>
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<td>8,505</td>
<td>3,586</td>
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<td><strong>Facility for Rare Isotope Beams</strong></td>
<td>12,000</td>
<td>10,000</td>
<td>22,000</td>
<td>22,000</td>
<td>...</td>
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<tr>
<td><strong>12 GeV CEBAF Upgrade (TPC)</strong></td>
<td>20,000</td>
<td>35,928</td>
<td>50,000</td>
<td>43,072</td>
<td>-6,928</td>
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<td><strong>Other</strong></td>
<td>12,540</td>
<td>12,430</td>
<td>12,889</td>
<td>12,970</td>
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<td>BNL General Purpose Equipment</td>
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<td>2,006</td>
<td>3,000</td>
<td>2,000</td>
<td>-1,000</td>
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<tr>
<td>Other (DOE/SC obligations)</td>
<td>2,251</td>
<td>2,048</td>
<td>2,770</td>
<td>4,015</td>
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<td><strong>Total, Other</strong></td>
<td>19,701</td>
<td>16,484</td>
<td>18,659</td>
<td>18,985</td>
<td>+326</td>
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<tr>
<td><strong>TOTAL NUCLEAR PHYSICS</strong></td>
<td>535,000</td>
<td>540,114</td>
<td>547,387</td>
<td>526,938</td>
<td>-20,449</td>
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</table>
Medium Energy Nuclear Physics

<table>
<thead>
<tr>
<th></th>
<th>FY 2012 Approp</th>
<th>FY 2013 Request</th>
<th>FY 2013 to FY2012 Change $k</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research</td>
<td>37,296</td>
<td>35,374</td>
<td>-1,922</td>
<td>-5.2%</td>
</tr>
<tr>
<td>TJNAF Operations</td>
<td>77,372</td>
<td>80,651</td>
<td>+3,279</td>
<td>+4.2%</td>
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<tr>
<td>SBIR/STTR/Other</td>
<td>17,909</td>
<td>19,235</td>
<td>+1,326</td>
<td>+7.4%</td>
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<tr>
<td>Total</td>
<td>132,577</td>
<td>135,260</td>
<td>+2,683</td>
<td>+2.0%</td>
</tr>
</tbody>
</table>

- University and laboratory research is reduced 5.8% relative to FY 2012 and is focused on preparations for the 12 GeV program overall and analysis of 6 GeV data. Research is also supported for efforts with polarized proton beams at RHIC.
- Decrease is partially offset by a small shift of a lab research effort from the Heavy Ion subprogram.
- Increase in mandatory contributions to the SBIR/STTR programs - legislatively increased levels (2.95% of non-capital funding in FY 2012 and 3.05% in FY 2013)
- Increase in required contributions to DOE’s working capital fund and other obligations in the NP programs.
- There are no dedicated beam hours for research as the 12 GeV CEBAF Upgrade project is implemented - important maintenance and improvements of the existing facility continue in preparation for post-construction
- Majority of the increase is for Other Project Costs (e.g. commissioning) for the 12 GeV CEBAF Upgrade project, which is requested according the project baseline.
Heav Ion Nuclear Physics

<table>
<thead>
<tr>
<th></th>
<th>FY 2012 Approp</th>
<th>FY 2013 Request</th>
<th>FY 2013 to FY 2012 Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research</td>
<td>39,977</td>
<td>38,630</td>
<td>-1,347  -3.4%</td>
</tr>
<tr>
<td>RHIC Operations</td>
<td>157,617</td>
<td>156,571</td>
<td>-1,046  -0.7%</td>
</tr>
<tr>
<td>Other Operations</td>
<td>3,000</td>
<td>2,000</td>
<td>-1,000  -33.3%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>200,594</strong></td>
<td><strong>197,201</strong></td>
<td><strong>-3,393  -1.7%</strong></td>
</tr>
</tbody>
</table>

- University and laboratory research is reduced 5.8% relative to FY 2012 and will focus on the highest priority experiments at RHIC as well as commitments and experimental fees to allow U.S. researchers to exploit the RHIC Operations.
- Reduced funding will support an estimated 1,360 hours of operations for the highest priority experiments. Effective operation will be achieved by combining FY 2013 - FY 2014 running into a single back-to-back run bridging the two fiscal years.
- Impacts of constrained FY 2012 funding, including a voluntary reduction in force at RHIC and one-time cuts to materials and supplies, are still being assessed and may further impact FY 2013 levels of operations.
- Decrease for lab-wide General Purpose Equipment at BNL.

- Partially offsetting the decrease is an increase for continued fabrication of the STAR HFT MIE to detect particles containing charm quarts at RHIC.

Relativistic Heavy Ion Collider (RHIC) at BNL
### Low Energy Nuclear Physics

<table>
<thead>
<tr>
<th></th>
<th>FY 2012 Approp</th>
<th>FY 2013 Request</th>
<th>FY 2013 to FY2012 Change $k</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
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<td>48,946</td>
<td>-3,248</td>
<td>-6.2%</td>
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<tr>
<td>ATLAS Operations</td>
<td>16,048</td>
<td>16,429</td>
<td>+381</td>
<td>+2.4%</td>
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<tr>
<td>HRIBF Operations</td>
<td>6,821</td>
<td>6,479</td>
<td>-342</td>
<td>-5.0%</td>
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<tr>
<td>Other Operations</td>
<td>8,664</td>
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<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>105,727</strong></td>
<td><strong>98,018</strong></td>
<td><strong>-7,709</strong></td>
<td><strong>-7.3%</strong></td>
</tr>
</tbody>
</table>

- University and laboratory research in nuclear structure, nuclear astrophysics, neutron physics and neutrino physics is reduced 5.8% relative to FY 2012. Additional decrease associated with the reduced research effort at HRIBF.
- Last year of support in FY 2013 for the Majorana Demonstrator R&D project.
- Final year of funding in FY 2012 for the CUORE MIE.
- Reductions are partially offset by support for modest R&D effort on the electric dipole moment of the neutron, by operations support the KATRIN experiment and the GRETINA MIE for nuclear structure research, both of which were completed in FY 2011.
- Maintain operations at the ATLAS national user facility.
- Funding associated with HRIBF in FY 2013 supports D&D-related activities following the end of its operation as a national user facility in FY 2012.
- Decrease in funding reflects one-time support in FY.2012 of dewatering and minimal sustenance of operations activities at the Homestake Mine in South Dakota.
- Continued support for FRIB activities in support of achieving CD-2/3, “Approve Project Baseline”/ “Approve Construction Start.”

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Gammasphere Detector at ATLAS (ANL)
Unanticipated Intellectual Connections to Hot QCD Research at RHIC

RHIC results have established ties to other forefront science:

- String Theory studies of black hole behavior led to prediction of a conjectured quantum lower bound on $\eta/s$ — a “perfect fluid”
- Ultra-cold atomic gases, at temperatures 19 orders of magnitude below QGP, can also be “nearly perfect liquids”
- Similar liquid behavior seen and studied in a number of strongly correlated condensed matter systems
- Symmetry-violating bubbles in QGP analogous to speculated cosmological origin of baryon-antibaryon imbalance in universe
- Power spectrum of flow analogous to power spectrum of cosmic microwave background, used to constrain baryon acoustic oscillations & dark energy

Trapped ultra-cold atom clouds

Organic superconductors

CMB fluctuations