U.S. DEPARTMENT OF ENERGY | Office of Science

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

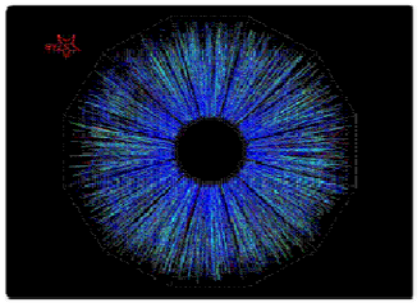
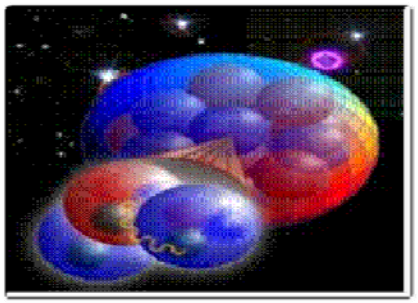
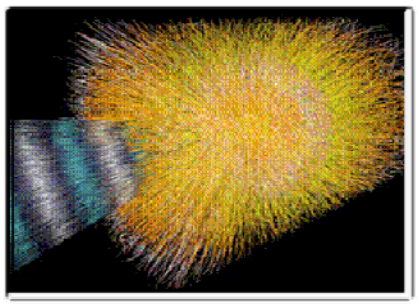
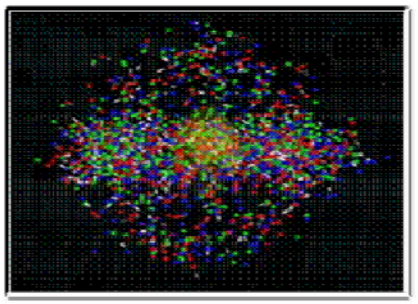
The Scientific Challenges:

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

(Dollars in Thousands)

	FY 2011 Current	FY 2012 Enacted	FY 2013 Request	$	%
Advanced Scientific Computing Research	410,317	440,868	455,593	+14,725	+3.3%
Basic Energy Sciences	1,638,511	1,688,093	1,799,592	+111,499	+6.6%
Biological and Environmental Research	595,246	609,557	625,347	+15,790	+2.6%
Fusion Energy Sciences	367,257	400,996	398,324	-2,672	-0.7%
High Energy Physics	775,578	790,860	776,521	-14,339	-1.8%
Nuclear Physics	527,684	547,387	526,938	-20,449	-3.7%
Workforce Development for Teachers and Scientists	22,600	18,500	14,500	-4,000	-21.6%
Science Laboratories Infrastructure	125,748	111,800	117,790	+5,990	+5.4%
Safeguards and Security	83,786	80,573	84,000	+3,427	+4.3%
Science Program Direction	202,520	185,000	202,551	+17,551	+9.5%
SBIR/STTR (SC funding)	108,418	—	—		
Subtotal, Office of Science	4,857,665	4,873,634	5,001,156		
SBIR/STTR (Other DOE funding)	54,618	—	—		
Use of prior year balances	-15,000	—	-9,104		
Total, Science Appropriation	4,897,283	4,873,634	4,992,052	+118,418	+2.4%

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

Budget Structure/Subprogram	FY 2011 Approp	FY 2012 Approp	FY 2013 Request	FY 2013 to FY2012 Change $k	FY 2013 to FY2012 Change %
Medium Energy Nuclear Physics	134,563	132,577	135,260	+2,683	+2.0%
Heavy Ion Nuclear Physics	201,594	200,594	197,201	-3,393	-1.7%
Low Energy Nuclear Physics	105,424	105,727	98,018	-7,709	-7.3%
Nuclear Theory	42,935	39,407	37,179	-2,228	-5.7%
Isotope Program	19,670	19,082	18,708	-374	-2.0%
Construction	35,928	50,000	40,572	-9,428	-18.9%
Total *	**540,114**	**547,387**	**526,938**	**-20,449**	**-3.7%**

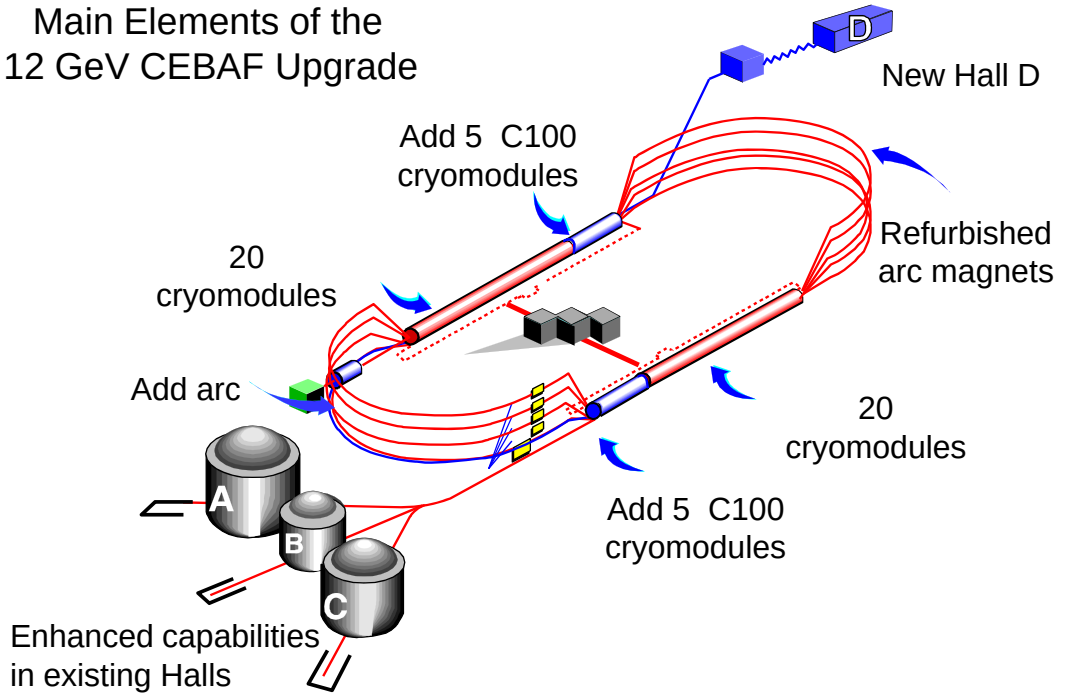
- FY 2011 includes SBIR/STTR for comparability

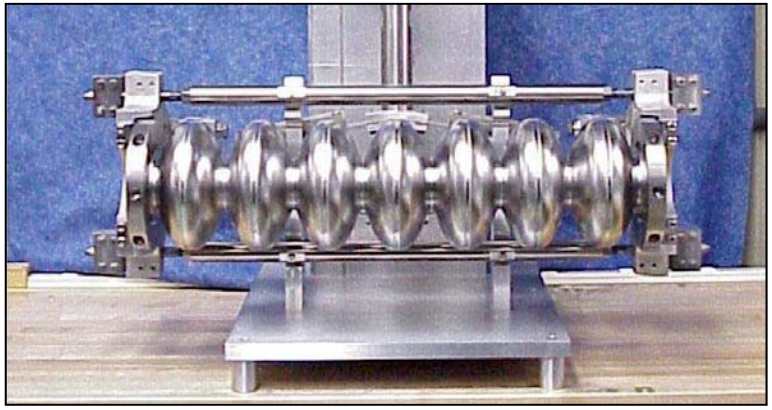
The 12 GeV CEBAF Upgrade at TJNAF is 60% Complete

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





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 cyromodules 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

Hall D Interior

Third C-100 Cryomodule transferred to tunnel

Central Helium Liquefier-2 installation

Hall B Pre-Shower Calorimeter

- 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%

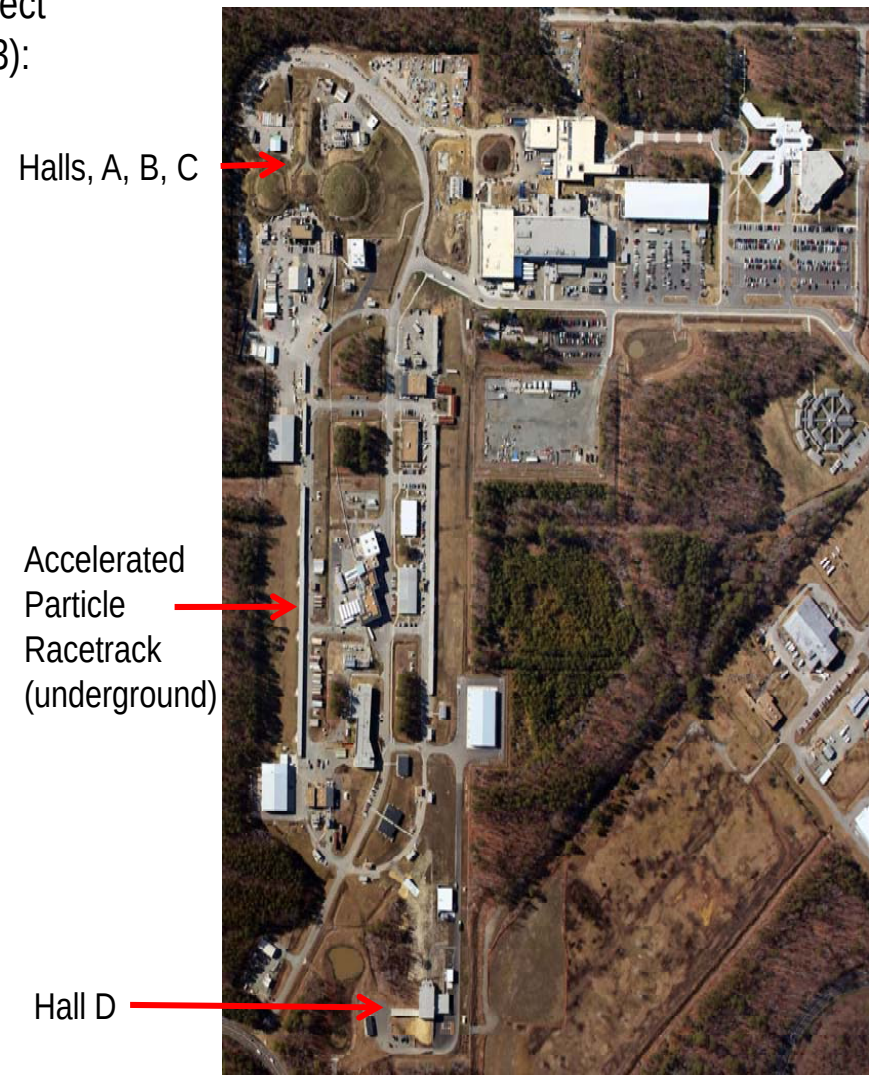
Hall C Dipole Prototype Coil

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):

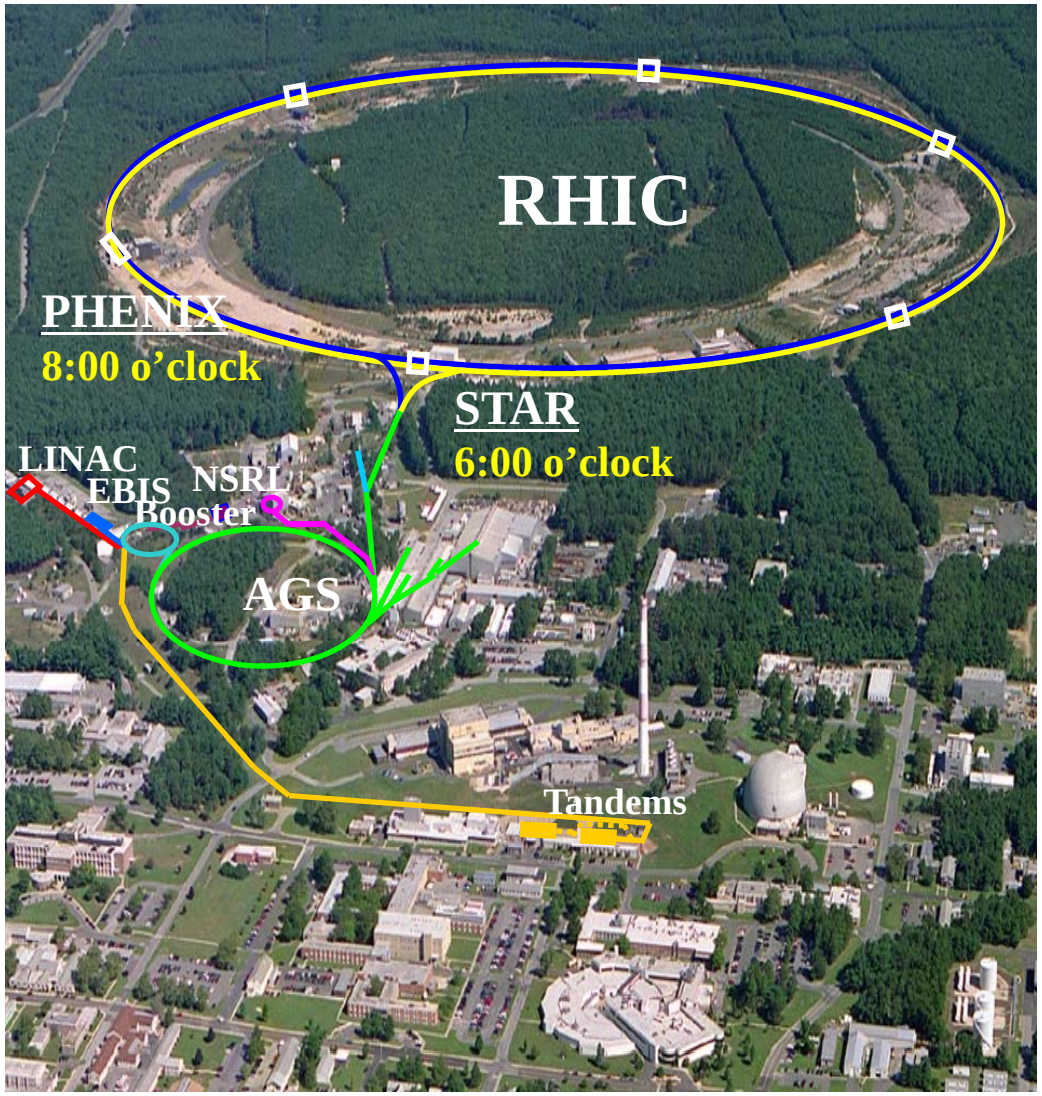
- The 12 month shutdown for construction activities is extended to 18 months, eliminating time for machine studies in FY 2013 prior to the restart of operations, increasing the risk to machine operational reliability.
- There is a 6 month to one year delay in the start of data taking and scientific return 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

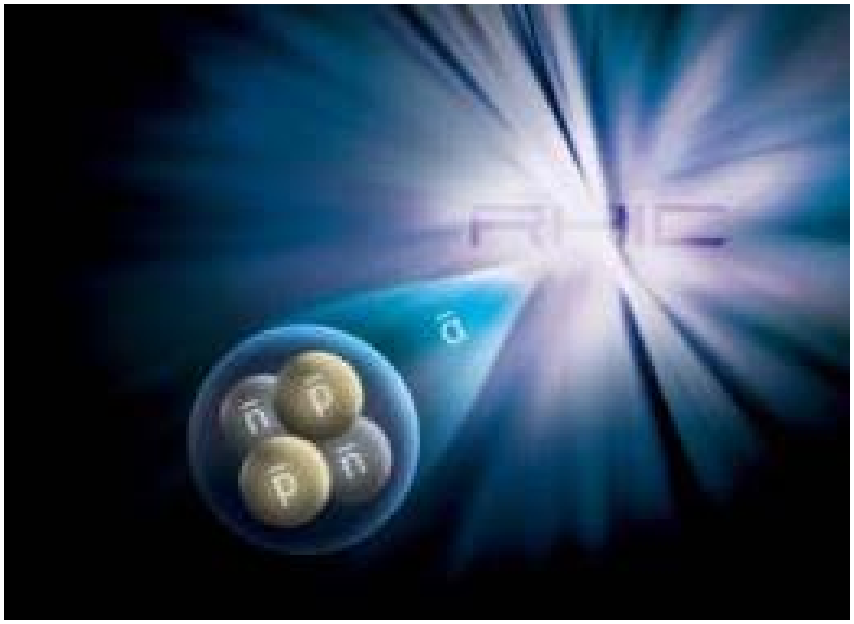


FY2011 Accomplishments at the Relativistic Heavy Ion Collider

- 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



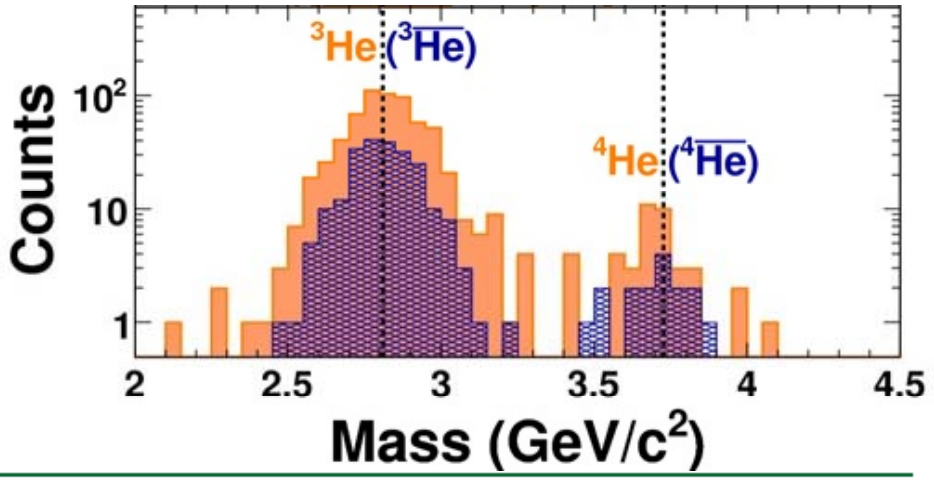
The graph below shows particle counts by mass, showing ordinary helium nuclei (He-3 and He-4) in orange, and their antimatter counterparts (antihelium-3 and antihelium-4) in blue. The newly discovered antimatter nuclei, antihelium-4, are cleanly separated from the lighter isotopes, and are at the correct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

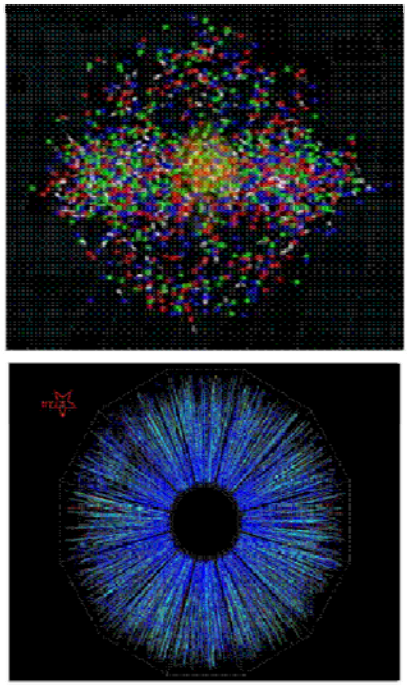
Third in the Discover Magazine Top Ten Physics and Math Stories for 2011: "Helium's Anti-Matter Twin Created"

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

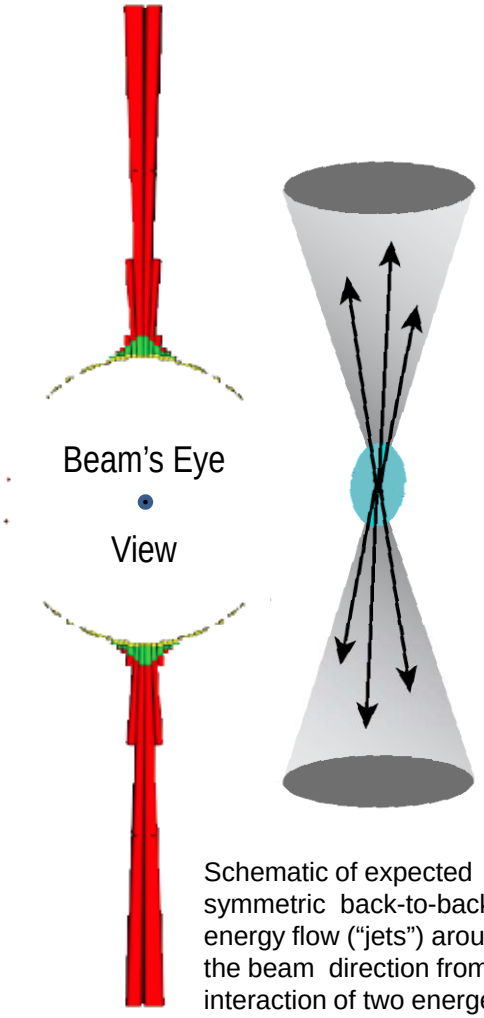
- University and laboratory research is reduced 5.8% relative to FY 2012 and will focus on the highest priority experiments at RHIC.
- Reduced funding will support an estimated 1,360 hours of operations for the highest priority experiments. This is a decrease of 1,030 hours relative to FY 2012.
- Effective 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.



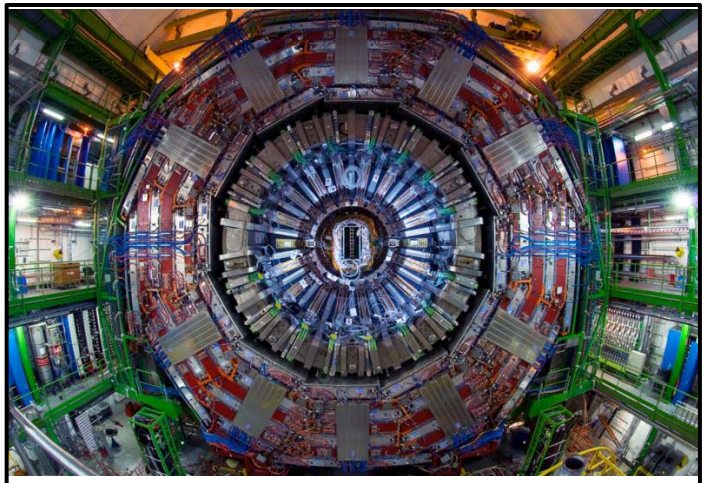
Above: Side view of Monte Carlo Simulation of Perfect Liquid produced in head-on collisions of gold nuclei at RHIC. Bottom: Head on view of measured pattern of sub-atomic particles emitted in RHIC collisions

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



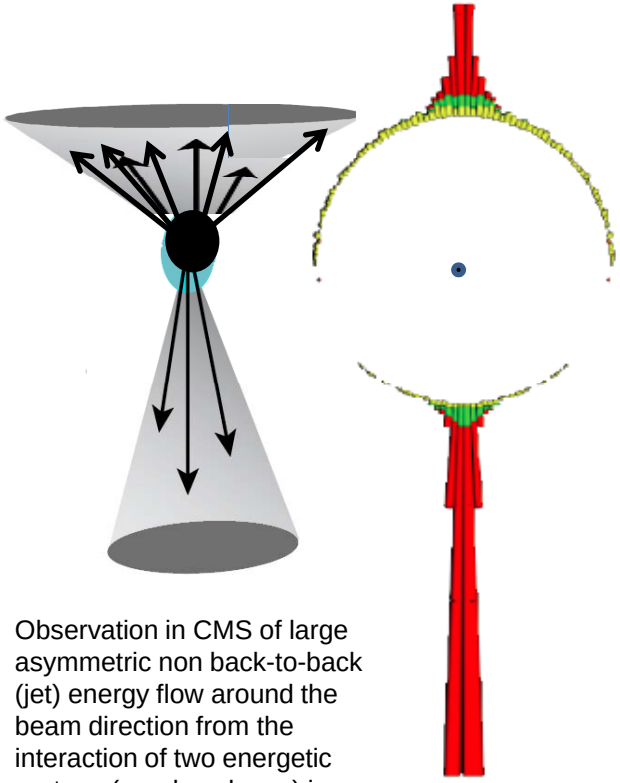
Schematic of expected symmetric back-to-back energy flow ("jets") around the beam direction from the interaction of two energetic partons (quarks, gluons) in proton – proton collisions



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).

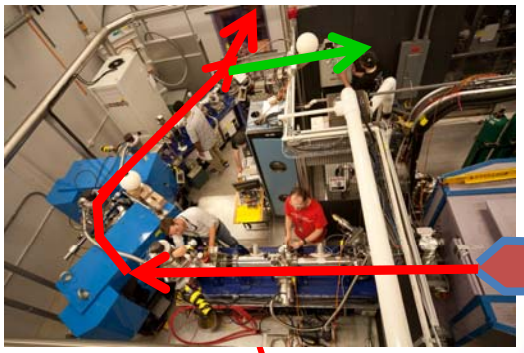
The results show that this new form of matter, believed to have influenced the evolution of the early universe, has unique properties and interacts more strongly than any matter previously produced in the laboratory.

Energy deposition in the CMS detector at the Large Hadron Collider (LHC) as a function of angle around the beam direction



Observation in CMS of large asymmetric non back-to-back (jet) energy flow around the beam direction from the interaction of two energetic partons (quarks, gluons) in relativistic nucleus-nucleus collisions

Argonne Tandem Linac Accelerator System Layout

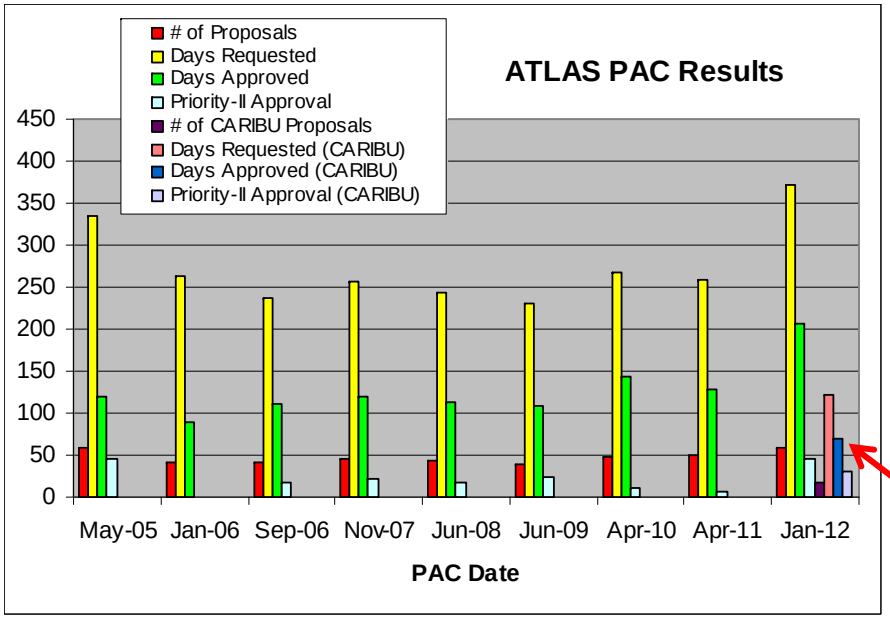


Experimental Support & ATLAS Operations: Statistics

	1st Qtr FY11	2nd Qtr FY11	3rd Qtr FY11	4th Qtr FY11	Total FY11
Research hours	896.8	557.2	1081.6	1206.3	3741.9
Beam studies hours	389.6	162.0	280.0	165.1	996.7
Setup/tuning hours	119.2	124.9	293.8	192.8	730.7
Total Delivered Operating Hours	1405.6	845.1	1655.4	1564.2	5470.3
Failure & unscheduled shutdown hours	43.4	121.8	164.1	88.4	417.7
Total scheduled operating hours	1449.0	966.9	1819.5	1652.6	5888.0
FY11 Baseline Estimate					5700 hours
80% of FY11 Baseline Estimate					4560 hours
Scheduled maintenance hours	231.4	376.4	157.0	179.3	944.1
Reliability	0.970	0.874	0.910	0.947	0.929

Reliability: 92%

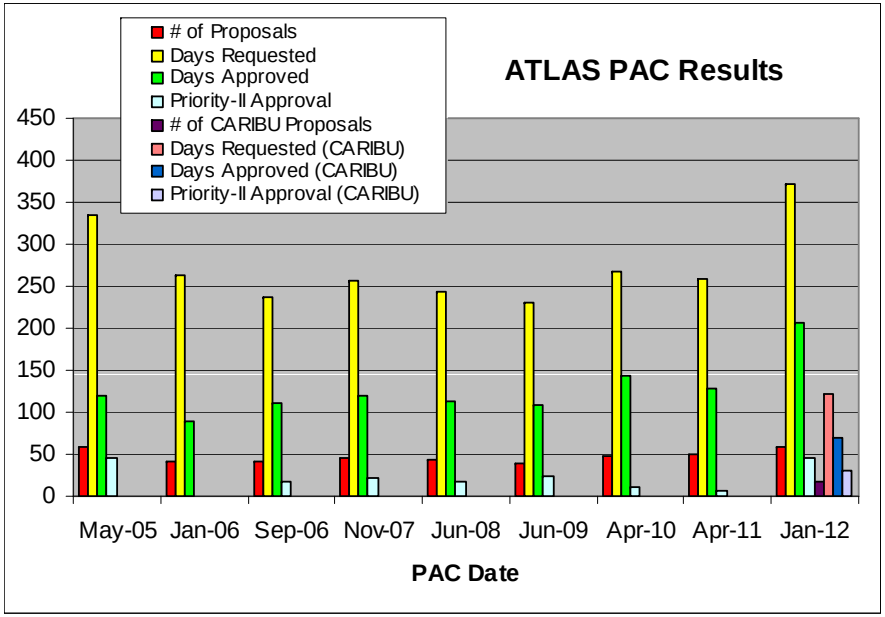
Mode of Operation: 7 days/week to address very high demand by Users



- 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)

Impacts of Reduced Funding in FY 2013 for ATLAS Operations and Research

- 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.

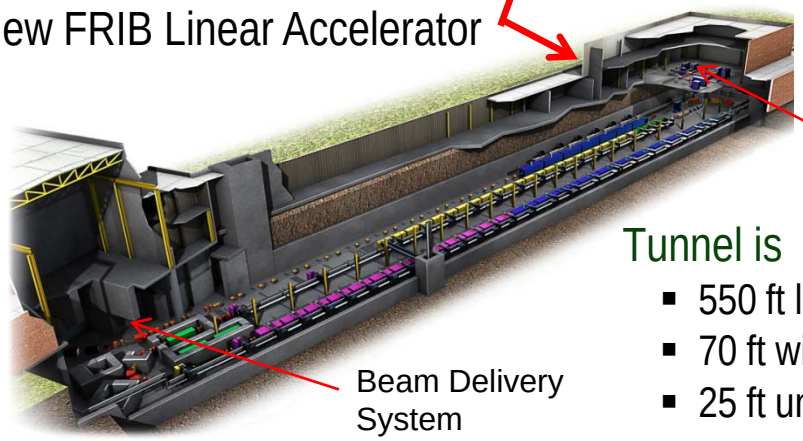


- Statistics from the ATLAS Program Advisory Committee (PAC) show a persistent trend which will increase until the start of FRIB
  - high number of proposals
  - oversubscription (the yellow versus the green)

Preparations for Construction of Facility for Rare Isotope Beams

Existing National Superconducting Cyclotron Laboratory

New FRIB Linear Accelerator



Tunnel is
- 550 ft long
- 70 ft wide
- 25 ft underground

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.

Status of the Project to Construct the Facility for Rare Isotope Beams

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.

Technological Breakthrough at Argonne National Lab for FRIB

A thin film of liquid lithium ~ 420 μg/cm^2 thick movies 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

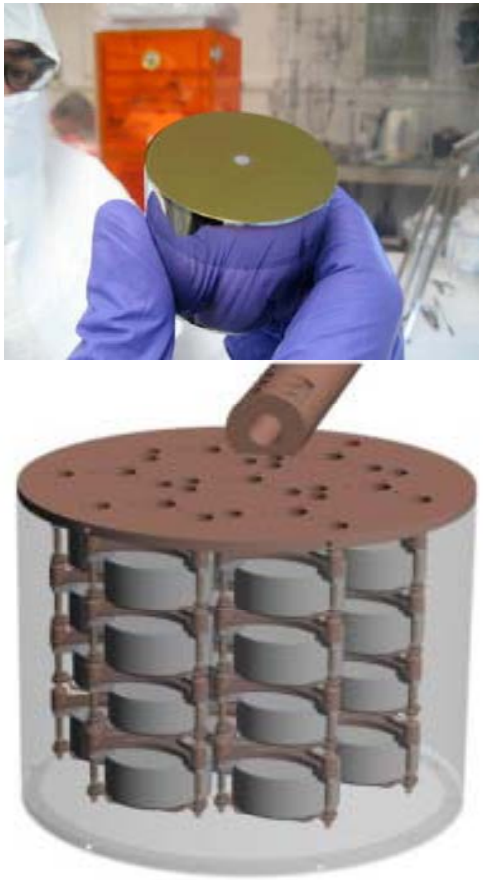
~10-15 FTE's out of 115 FTE (155 heads) currently working on the FRIB

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.

Germanium detector and the cryostat for the Majorana Demonstrator (MJD 40-kg ultra-clean Ge detector).



Nuclear Theory

	FY 2012 Approp	FY 2013 Request	FY 2013 to FY 2012 Change $k	%
Research	31,047	29,246	-1,801	-5.8%
SciDAC	1,000	1,000	0	0
Nuclear Data	7,360	6,933	-427	-5.8%
Total	**39,407**	**37,179**	**-2,228**	**-5.7%**

- 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.

LQCD Cluster

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

Isotopes and Radioisotopes in Short Supply Provided at Full Cost Recovery by the Office of Science to Support U.S. Needs and Industrial Competitiveness

Some key isotopes and radioisotopes and the companies that use them

Strontium-82, Rubidium-82	Imaging / Diagnostic cardiology
Germanium-68, Gallium-68	Calibration / PET scan imaging
Californium-252	Oil and gas exploration and manufacturingcontrols
Selenium-75	Radiography / Quality control
Actinium-225, Yttrium-90, Rhenium 188	Cancer / Infectious disease treatment
Nickel-63	Explosives detection at airports
Gadolinium-160, Neodymium-160	Tracers and contrast agents for biological agents
Iron-57, Barium-135	Standard sources for mass spectroscopy
Sulfur-34	Environmental monitoring
Rubidium-87	Atomic frequency / GPS applications
Lithium-6, Helium-3	Detection of Special Nuclear Materials
Samarium-154	Solar energy /transportation applications

Isotope Program

	FY 2012 Approp	FY 2013 Request	FY 2013 to FY 2012 Change $k	%
Research	4,827	4,453	-374	-7.7%
Operations	14,255	14,255	0	0
Total	**19,082**	**18,708**	**-374**	**-2.0%**

- 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.

Isotope Production Facility (LANL)

Brookhaven Linac Isotope Producer

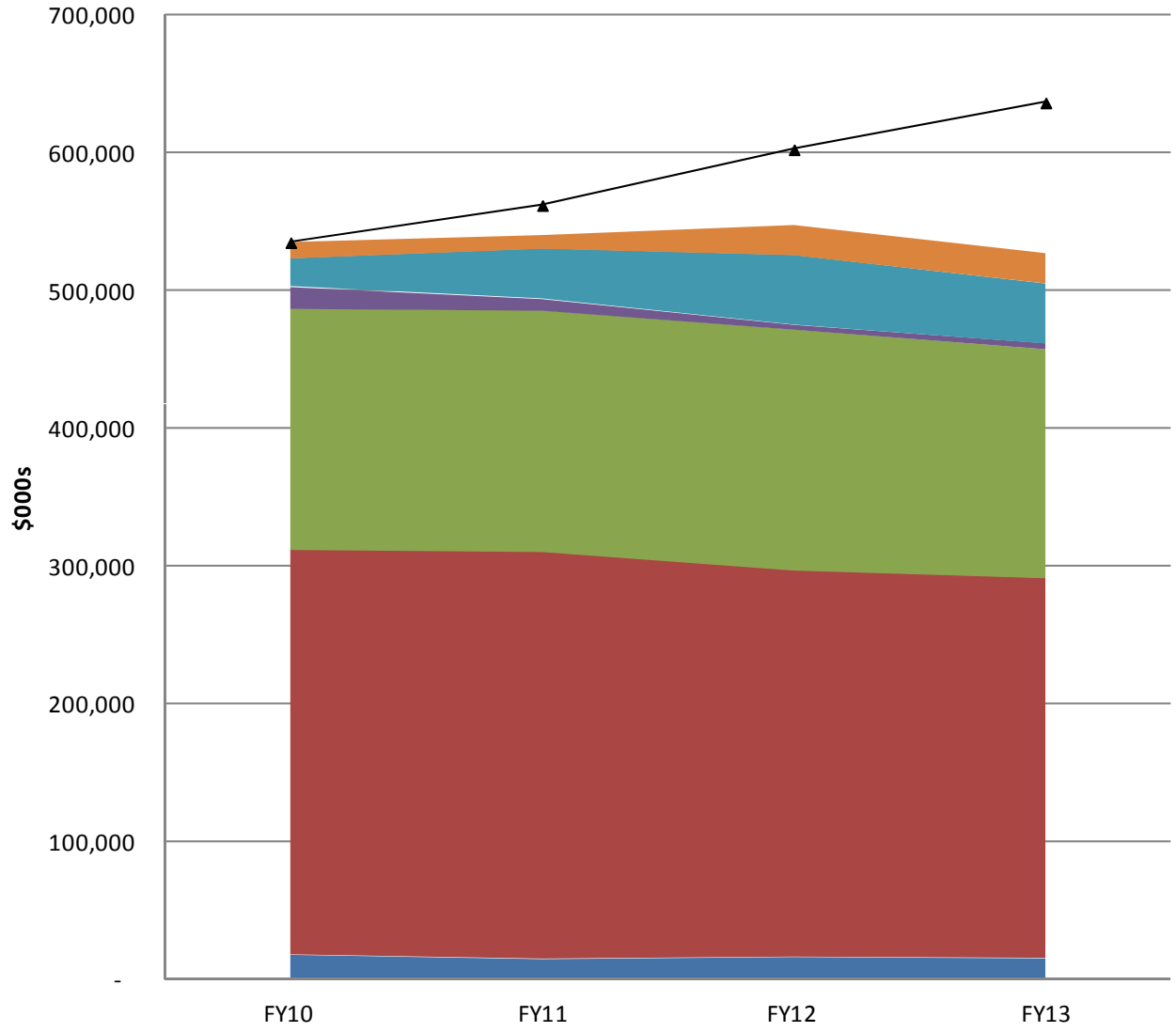
Radioisotope processing facilities

Office of Nuclear Physics FY 2013 Congressional Request

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.

Office of Nuclear Physics FY 2013 Congressional Request



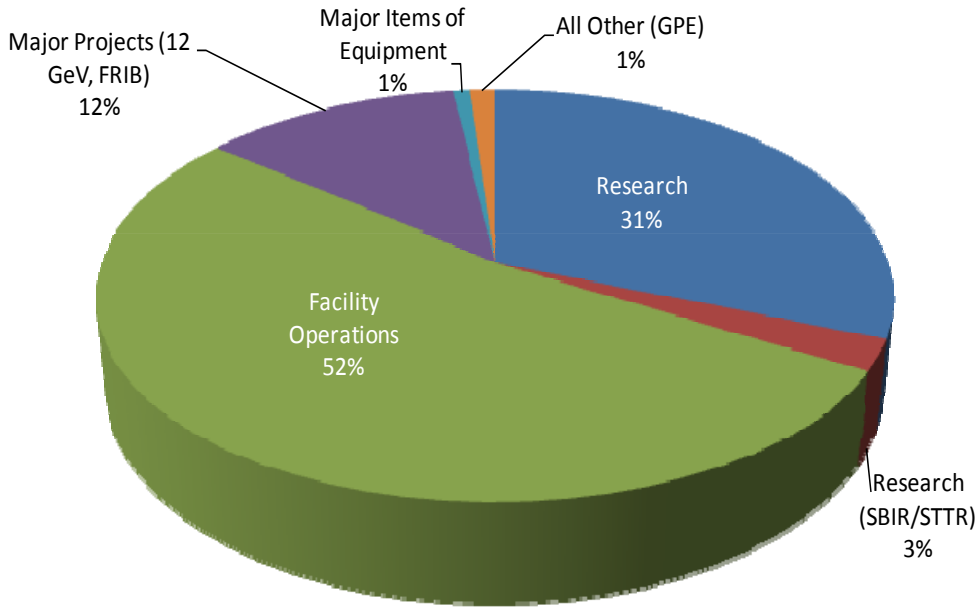
This chart reflects the enacted FY 2010-FY 2012 appropriations and the FY 2013 Congressional Request for the Nuclear Physics program.

The black line represents estimated funding needed to implement the majority of elements of the NSAC 2007 Long Range Plan (LRP).

FY 2013 Congressional Request
Nuclear Physics by Major Category

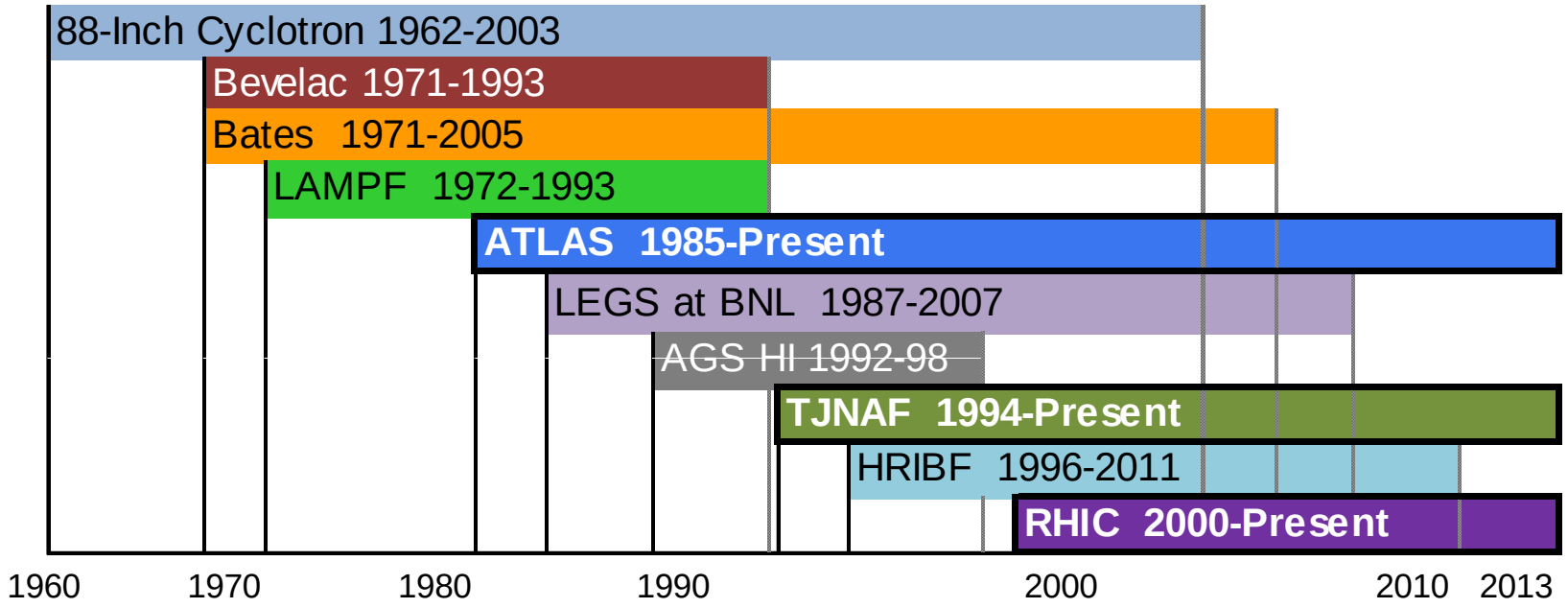
66% of the FY 2013 NP budget supports operations or construction of facilities & instrumentation

The percentage devoted to major projects is 12% in FY 2013



FY 2013 Congressional Request
Total = $526.9M

Timeline of DOE Nuclear Physics Facilities

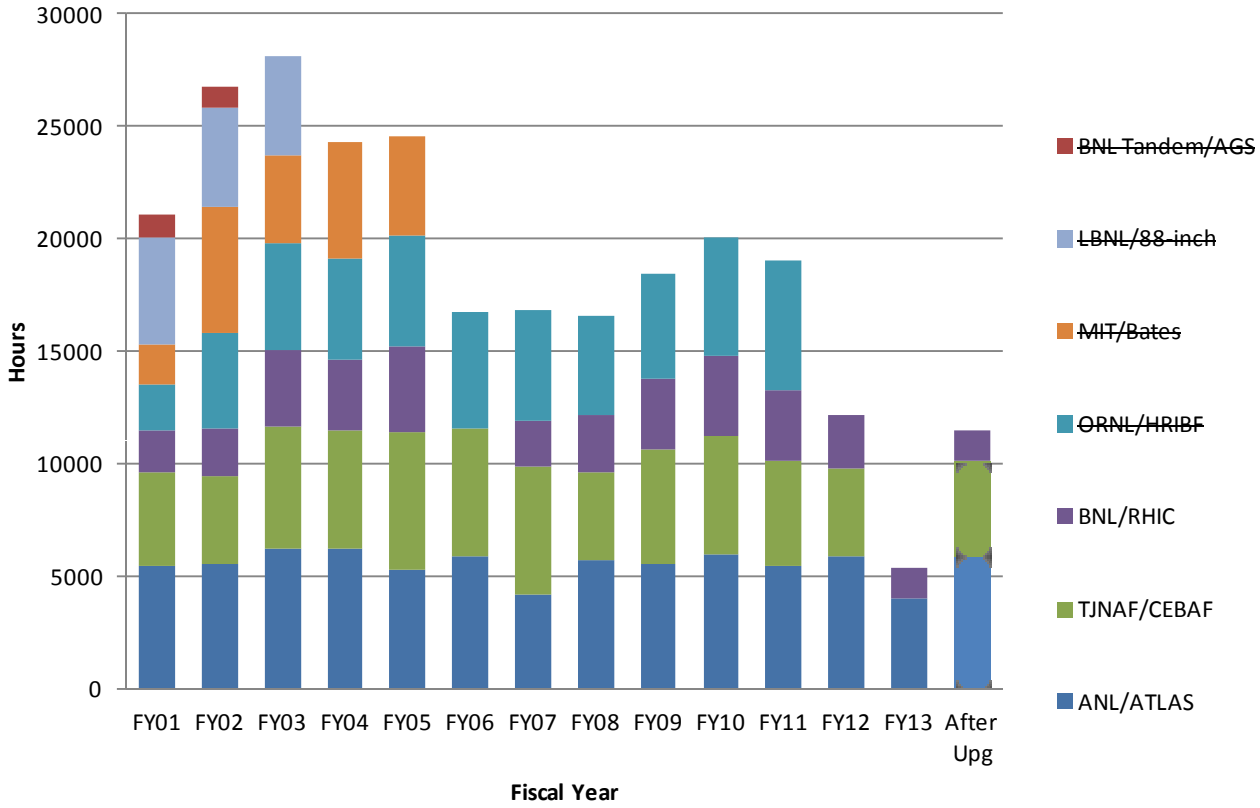


Additional Comments:

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



	FY 2013	Optimum	%
RHIC	1,360	4,100	33%
CEBAF	0	0	0%
ATLAS	4,000	5,000	80%
Total	5,360	9,100	38%

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

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;

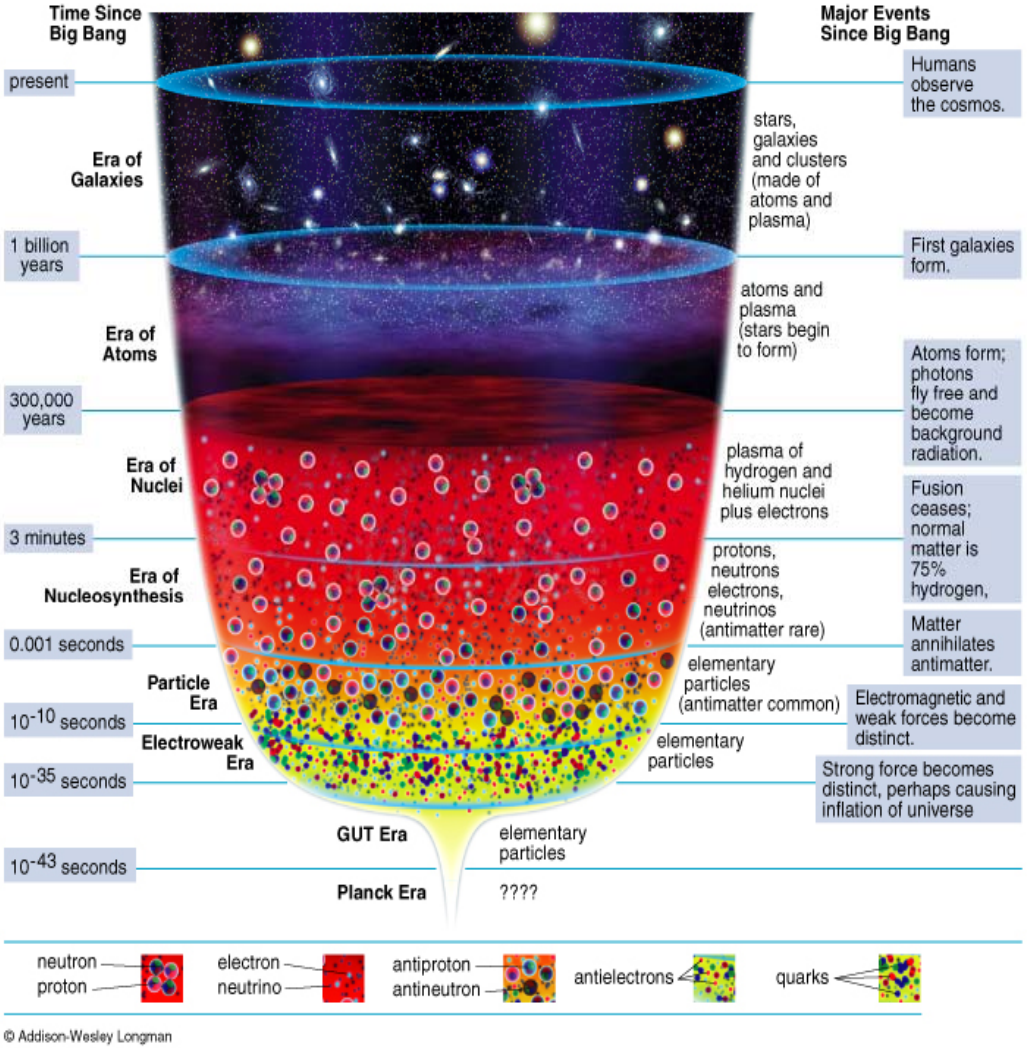
Nuclear-Reactions;

NP Discovery Horizon

Anti-Helium 4;
Proton Spin
Majorana/DIRAC Neutrino;
Perfect QGP Liquid

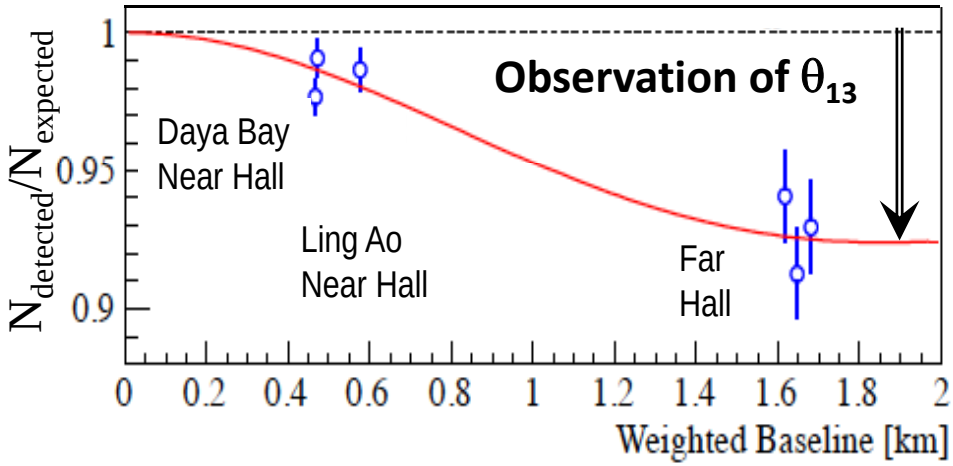
Neutron Beta Decay;
Neutron EDM;
Parity Violation
Searches;

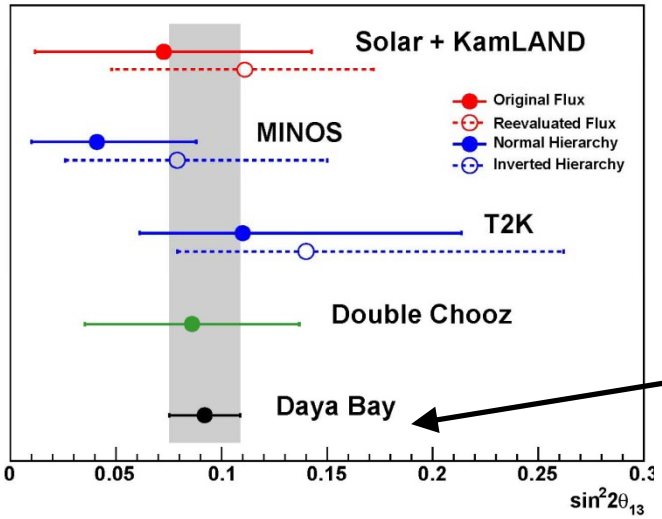
Evolution of the Universe



Exciting New Science "Hot off the Presses"

Neutrino mixing angle θ_{13} is non-zero at 5.2σ





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, θ_{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 θ_{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

	FY 2010 Approp	FY 2011 Approp	FY 2012 Approp	FY 2013 Cong Request	FY 2013 vs. FY 2012	
Research	**173,114**	**173,525**	**172,365**	**162,432**	**-9,933**	**-5.8%**
National User Facilities						
RHIC	157,195	159,385	157,617	156,571	-1,046	-0.7%
CEBAF	83,327	82,563	77,372	78,151	+779	+1.0%
ATLAS	16,216	16,196	16,048	16,429	+381	+2.4%
HRIBF	17,080	17,165	6,821	...	-6,821	-100.0%
Total, National User Facilities	**273,818**	**275,309**	**257,858**	**251,151**	**-6,707**	**-2.6%**
Other Facilty Operations						
Isotope Production Facilities	16,116	15,610	14,255	14,255	...	...
88-Inch Cyclotron	4,089	4,089	4,000	4,000	...	...
ORELA	164	164	164	164	...	...
HRIBF D&D	...	...	...	6,479	+6,479	+100.0%
Homestake De-watering	...	500	4,500	...	-4,500	-100.0%
Total, Other Facility Operations	**20,369**	**20,363**	**22,919**	**24,898**	**+1,979**	**+8.6%**
Major Items of Equipment (TPC)						
GRETINA	730	...	...	...	...	...
ALICE EMCal	5,000	1,205	...	...	...	...
nEDM	4,500	2,100	...	...	...	...
CUORE	3,088	800	536	...	-536	-100.0%
STAR HFT	2,680	4,400	3,050	4,400	+1,350	+44.3%
Total, MIEs	**15,998**	**8,505**	**3,586**	**4,400**	**+814**	**+22.7%**
Facility for Rare Isotope Beams	**12,000**	**10,000**	**22,000**	**22,000**	...	...
12 GeV CEBAF Upgrade (TPC)	**20,000**	**35,928**	**50,000**	**43,072**	**-6,928**	**-13.9%**
Other						
SBIR/STTR	12,540	12,430	12,889	12,970	+81	+0.6%
BNL General Purpose Equipment	4,910	2,006	3,000	2,000	-1,000	-33.3%
Other (DOE/SC obligations)	2,251	2,048	2,770	4,015	+1,245	+44.9%
Total, Other	**19,701**	**16,484**	**18,659**	**18,985**	**+326**	**+1.7%**
TOTAL NUCLEAR PHYSICS	**535,000**	**540,114**	**547,387**	**526,938**	**-20,449**	**-3.7%**

Medium Energy Nuclear Physics

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

- 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.

CEBAF Jefferson Laboratory

- 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.

Heavy Ion Nuclear Physics

	FY 2012 Approp	FY 2013 Request	FY 2013 to FY 2012 Change $k	%
Research	39,977	38,630	-1,347	-3.4%
RHIC Operations	157,617	156,571	-1,046	-0.7%
Other Operations	3,000	2,000	-1,000	-33.3%
Total	**200,594**	**197,201**	**-3,393**	**-1.7%**

- 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 ALICE EMCal MIE and other detectors at the LHC.
- 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

- 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.

Low Energy Nuclear Physics

	FY 2012 Approp	FY 2013 Request	FY 2013 to FY2012 Change $k	FY 2013 to FY2012 Change %
Research	52,194	48,946	-3,248	-6.2%
ATLAS Operations	16,048	16,429	+381	+2.4%
HRIBF Operations	6,821	6,479	-342	-5.0%
Other Operations	8,664	4,164	-4,500	-51.9%
FRIB	22,000	22,000	0	0
Total	**105,727**	**98,018**	**-7,709**	**-7.3%**

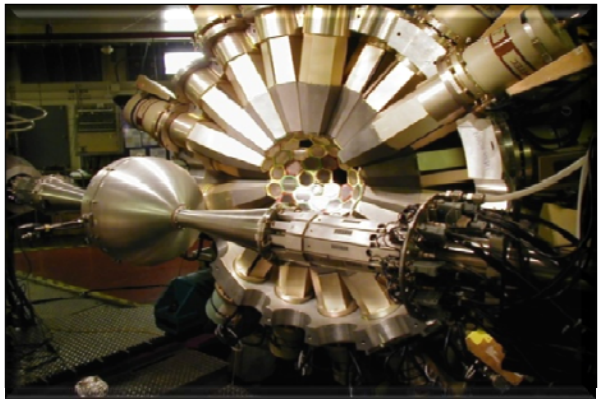
- University and laboratory research in nuclear structure, nuclear astrophysics, neutron physics and neutrino physics is reduced 5.8% relative to FY 2012. Additional decrease associated with the reduced research effort at HRIBF.
  - Last year of support in FY 2013 for the Majorana Demonstrator R&D project.
  - 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.

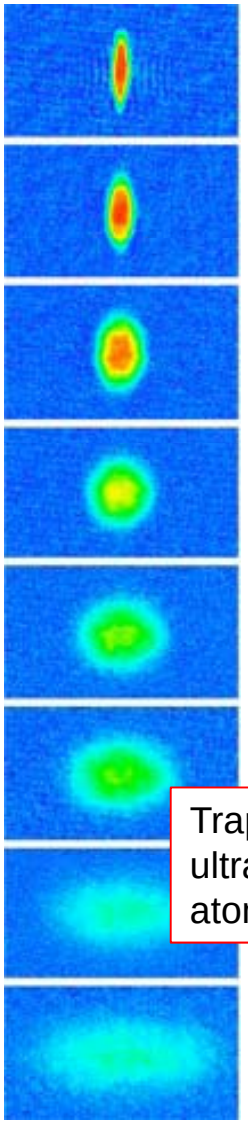
- Decrease in funding reflects one-time support in FY.2012 of dewatering and minimal sustenance of operations activities at the Homestake Mine in South Dakota.

- Continued support for FRIB activities in support of achieving CD-2/3, “Approve Project Baseline”/ “Approve Construction Start.”



Gammasphere Detector at ATLAS (ANL)

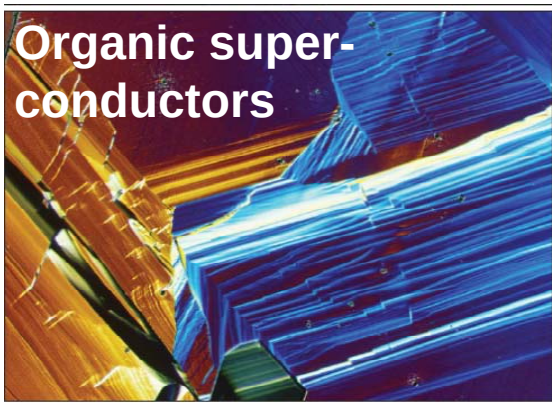
Unanticipated Intellectual Connections to Hot QCD Research at RHIC

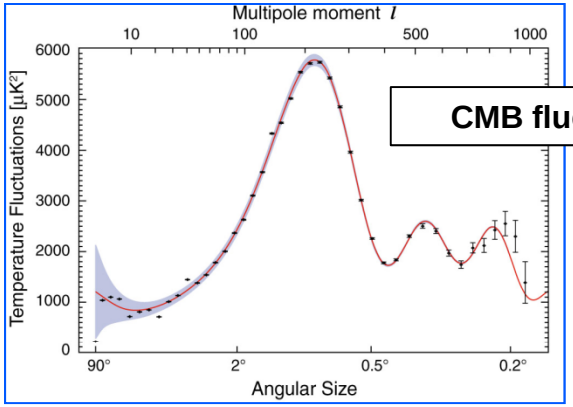


Trapped ultra-cold atom clouds

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 η/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





CMB fluctuations