U.S. DEPARTMENT OF ENERGY | Office of Science

# DOE Office of Nuclear Physics Overview


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for Nuclear Physics


March 2, 2011

Nuclear Science Advisory Committee Meeting

# Office of Science FY 2012 Budget Request to Congress

(dollars in thousands)

| | FY 2010 Current Approp. | FY 2011 President's Request | FY 2011 Full Year CR | FY 2012 President's Request | FY 2012 vs. FY 2010 | |
|---|---|---|---|---|---|---|
| Advanced Scientific Computing Research | 383,199 | 426,000 | 394,000 | 465,600 | +82,401 | +21.5% |
| Basic Energy Sciences | 1,598,968 | 1,835,000 | 1,636,500 | 1,985,000 | +386,032 | +24.1% |
| Biological and Environmental Research | 588,031 | 626,900 | 604,182 | 717,900 | +129,869 | +22.1% |
| Fusion Energy Sciences | 417,650 | 380,000 | 426,000 | 399,700 | -17,950 | -4.3% |
| High Energy Physics | 790,811 | 829,000 | 810,483 | 797,200 | +6,389 | +0.8% |
| Nuclear Physics | 522,460 | 562,000 | 535,000 | 605,300 | +82,840 | +15.9% |
| Workforce Development for Teachers and Scientists | 20,678 | 35,600 | 20,678 | 35,600 | +14,922 | +72.2% |
| Science Laboratories Infrastructure | 127,600 | 126,000 | 127,600 | 111,800 | -15,800 | -12.4% |
| Safeguards and Security | 83,000 | 86,500 | 83,000 | 83,900 | +900 | +1.1% |
| Science Program Direction | 189,377 | 214,437 | 189,377 | 216,863 | +27,486 | +14.5% |
| **Subtotal, Office of Science** | **4,721,774** | **5,121,437** | **4,826,820** | **5,418,863** | **+697,089** | +14.8% |
| Small Business Innovation Research/ Technology Transfer (SBIR/STTR) (SC portion) | 107,352 | … | … | … | -107,352 | -100.0% |
| Congressionally-directed projects | 74,737 | … | … | … | -74,737 | -100.0% |
| Undistributed | … | … | 76,890 | … | … | … |
| Use of prior year balances | -153 | … | … | -2,749 | -2,596 | -1,696.7% |
| **Subtotal, Office of Science** | **4,903,710** | **5,121,437** | **4,903,710** | **5,416,114** | **+512,404** | +10.4% |
| SBIR/STTR (transfer from other DOE programs) | 60,177 | … | … | … | -60,177 | -100.0% |
| **Total, Office of Science** | **4,963,887** | **5,121,437** | **4,903,710** | **5,416,114** | **+452,227** | +9.1% |

Continuing Resolution (CR) column reflects the current CR (P.L. 111-322), annualized to a full year. Funding amounts reflect the FY 2010 appropriation level prior to the SBIR/STTR transfer. Funding on the undistributed line reflects FY 2010 Congressionally directed project funding prior to the SBIR/STTR transfer.

# Nuclear Physics FY 2012 Congressional Request

| | FY 2010 Approp. | FY 2010 Approp. with SBIR/STTR | FY 2012 Request | FY 2010 to FY2012 Change $k | % | FY 2010 with SBIR/STTR to FY2012 Change $k | % |
|---|---|---|---|---|---|---|---|
| Medium Energy | 122,113 | 127,481 | 130,380 | +8,267 | +6.8% | +2,899 | +2.3% |
| Heavy Ion | 205,063 | 210,725 | 219,984 | +14,921 | +7.3% | +9,259 | +4.4% |
| Low Energy | 116,216 | 117,642 | 126,536 | +10,320 | +8.9% | +8,894 | +7.6% |
| Theory | 39,952 | 39,952 | 42,166 | +2,214 | +5.5% | +2,214 | +5.5% |
| Isotope Program | 19,116 | 19,200 | 20,234 | +1,118 | +5.8% | +1,034 | +5.4% |
| Construction | 20,000 | 20,000 | 66,000 | +46,000 | +230.0% | +46,000 | +230.0% |
| **Total** | **522,460** | **535,000** | **605,300** | **+82,840** | **+15.9%** | **+70,300** | **+13.1%** |

**FRIB +$18M** (Low Energy)

**12 GeV Upgrade +$46M** (Construction)

- The FY 2012 budget request is dominated by continued support, as planned, for the two highest priorities in the 2007 Long Range Plan for Nuclear Science. **Of the $70.3M increase requested in FY 2012, $64M is for these two projects**.
  - The **12 GeV Continuous Electron Beam Accelerator Facility (CEBAF) Upgrade** which is being constructed at the Thomas Jefferson National Laboratory **(+$46M)**.
  - The **Facility for Rare Isotope Beams (FRIB)**, within the Low Energy subprogram, which is being constructed at Michigan State University **(+$18M)**.
- These investments in forefront facilities for new research capability, the first in the NP program in over ten years, will secure global U.S. leadership in research on the quark structure of nucleons, nuclear structure, and nuclear astrophysics.

# FY 2012 Congressional Request Funding Summary

| | FY 2010 Approp. | FY 2010 Approp. with SBIR/STTR | FY 2012 Request | FY 2010 to FY2012 Change $k | % | FY 2010 with SBIR/STTR to FY2012 Change $k | % |
|---|---|---|---|---|---|---|---|
| Research | 175,365 | 187,905 | 200,601 | +25,236 | +14.4% | +12,696 | +6.8% |
| Scientific User Facility Operations | 273,818 | 273,818 | 272,123 | -1,695 | -0.6% | -1,695 | -0.6% |
| Other Facility Operations | 20,369 | 20,369 | 25,390 | +5,021 | +24.7 % | +5,021 | +24.5% |
| Projects | | | | | | | |
| Major Items of Equipment | 15,998 | 15,998 | 6,186 | -9,812 | -61.3% | -9,812 | -61.3% |
| Facility for Rare Isotope Beams | 12,000 | 12,000 | 30,000 | +18,000 | +150.0% | +18,000 | +150.0% |
| 12 GeV CEBAF Upgrade | 20,000 | 20,000 | 66,000 | +46,000 | +230.0% | +46,000 | +230.0% |
| Other (BNL GPE) | 4,910 | 4,910 | 5,000 | +90 | +1.8% | +90 | +2.0% |
| **Total** | **522,460** | **535,000** | **605,300** | **+82,840** | **+15.9%** | **+70,300** | **+13.1%** |

- Crosscut of total funding by category across all NP subprograms.
- The FY 2010 column in blue includes the funds set-aside within NP for SBIR/STTR. This column is comparable to the FY 2012 request which also includes the SBIR/STTR funding.

# FY 2012 Congressional Request ($k)
## Nuclear Physics – Highlights

| | |
|---|---|
| **PLANNED PROFILE INCREASES FOR HIGH PRIORITY CONSTRUCTION PROJECTS** | **+$64,000** |
| ▪ **12 GeV Continuous Electron Beam Accelerator Facility Upgrade** – per baselined construction funding profile | + 46,000 |
| ▪ **Facility for Rare Isotope Beams (FRIB)** – per Cooperative Agreement with Michigan State University | + 18,000 |
| **FUNDING CHANGES IN THE REST OF THE NP PROGRAM** | **+ 6,300** |
| ▪ **DUSEL** – to support minimal, sustaining operations at the Homestake mine in South Dakota | + 5,000 |
| ▪ **Facility Operations**<br>▪ RHIC – 24 weeks of operations at increased luminosity (+$7.4M)<br>▪ CEBAF – 27 weeks of operations, maximum possible with 12 GeV installation schedule (+$0.6M)<br>▪ ATLAS – 39 weeks, including commissioning of new accelerator components (+$0.6M)<br>▪ Other Facilities (Isotope Facilities, 88-Inch, ORELA) and BNL GPE (+$0.1M) | + 8,675 |
| ▪ **HRIBF** – closure as a national user facility in FY 2012 to support higher priority activities within the NP program | - 10,259 |
| ▪ **Research** – core research is held flat with FY 2010 at universities and national laboratories except for targeted increases for build-up of Hall D experimental groups; R&D and operations associated with recently completed and new MIEs to optimize investments (RHIC experiments, FNPB, HI LHC, GRETINA, KATRIN, CUORE, Majorana); development of the experimental program at the recently completed FNPB; isotope production research (a redistribution of efforts previously categorized as operations); and Early Career Research Program awards. Increases are partially offset by decreases for SciDAC, shutdown of the Yale accelerator, and termination of RIB Science Initiatives. | + 10,196 |
| ▪ **Majorana Demonstrator R&D** ramps-up according to planned profile – effort to demonstrate proof-of-principle for neutrino-less double beta decay; initiated in FY 2010 | + 2,500 |
| ▪ **Major Items of Equipment**<br>▪ **STAR HFT** – ramps up per planned profile for RHIC high luminosity run in FY 2013 (+$1.9M)<br>▪ **nEDM** – slowed relative to project plans approved at CD-1 (-$3.4M)<br>▪ Funding completion for **ALICE EMCal, CUORE** and **GRETINA** per planned profiles (-$8.3M) | - 9,812 |
| **TOTAL NUCLEAR PHYSICS** | **+$70,300** |

# Major Items of Equipment FY 2012 Congressional Request

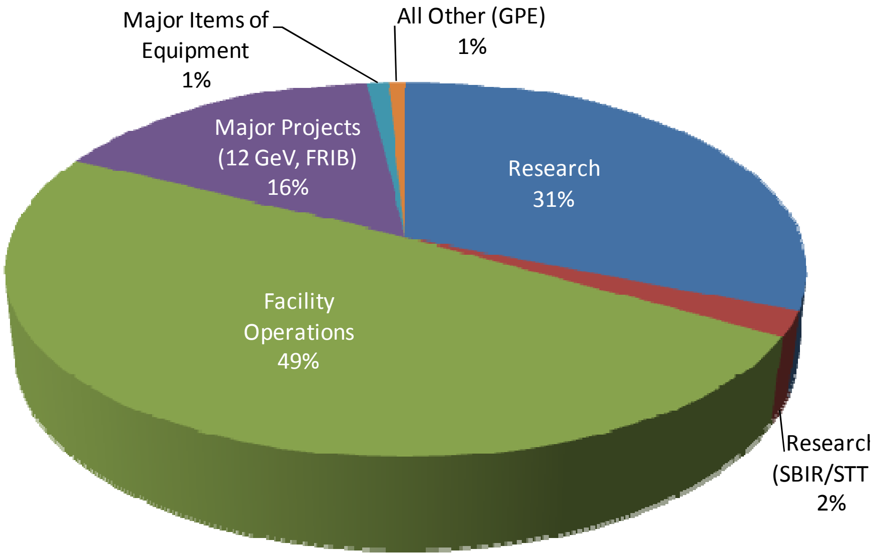
(dollars in thousands)

| | FY 2010 Approp. | FY 2011 Request | FY 2011 CR | FY 2012 Request | FY12 Request vs. FY10 Approp. | |
|---|---|---|---|---|---|---|
| | | | | | $ | % |
| **Heavy Ion MIEs** | | | | | | |
| Heavy Ion LHC Experiments (EMCal for ALICE) | 5,000 | 1,205 | 1,205 | 0 | -5,000 | -100.0% |
| PHENIX Silicon Vertex Tracker | 0 | 0 | 0 | 0 | +0 | ... |
| PHENIX Forward Vertex Detector | 0 | 0 | 0 | 0 | +0 | ... |
| STAR Heavy Flavor Tracker | 2,680 | 2,900 | 2,900 | 4,550 | +1,870 | +69.8% |
| **Total Heavy Ion MIEs** | **7,680** | **4,105** | **4,105** | **4,550** | **-3,130** | **-40.8%** |
| **Low Energy MIEs** | | | | | | |
| GRETINA Gamma-Ray Detector | 730 | 0 | 0 | | -730 | -100.0% |
| Neutron Electric Dipole Moment (nEDM) | 4,500 | 2,900 | 2,900 | 1,100 | -3,400 | -75.6% |
| Cryogenic Underground Observatory for Rare Events (CUORE) | 3,088 | 800 | 800 | 536 | -2,552 | -82.6% |
| Rare Isotope Beam Science Initiatives * | *[4,200]* | 5,000 | 0 | 0 | *[-4,200]* | *[-100%]* |
| **Total Low Energy MIEs** | **8,318** | **8,700** | **3,700** | **1,636** | **-6,682** | **-80.3%** |
| **TOTAL MIEs (TPC)** | **15,998** | **12,805** | **7,805** | **6,186** | **-9,812** | **-61.3%** |

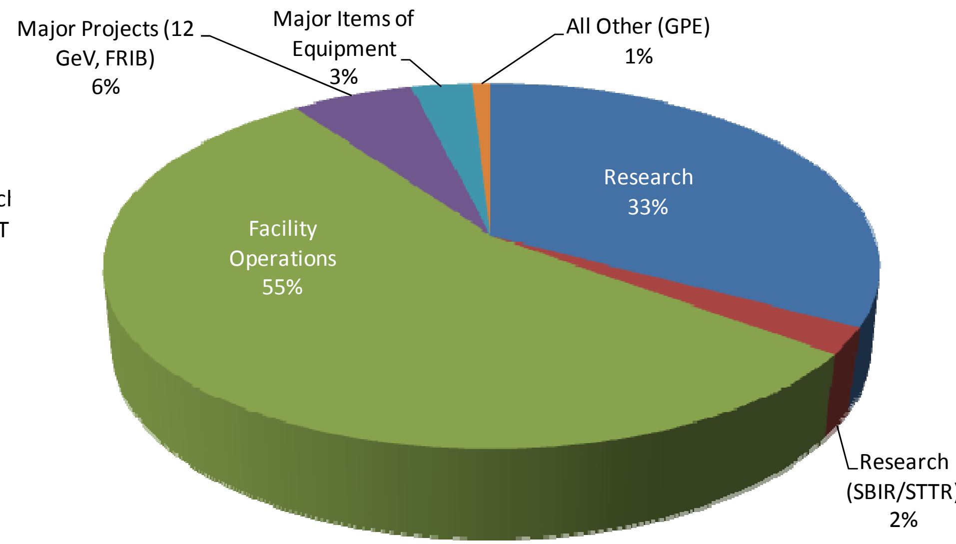
* The first peer-reviewed awards were made under RIB Science Initiatives in FY 2010. The four university awards and two laboratory awards totaling $4,200,000 were all under the MIE threshold and, therefore, are not included in the MIE total.

# FY 2012 Congressional Request Nuclear Physics by Major Function

**67% of the NP budget supports operations or construction of facilities & instrumentation**
**The percentage devoted to major projects grows to 16% in FY 2012**




**FY 2012 Congressional Request**
**Total = $605.3M**




**FY 2010 Appropriation**
**with SBIR/STTR**
**Total = $535.0M**

# Nuclear Physics

Discovering, exploring, and understanding all forms of nuclear matter

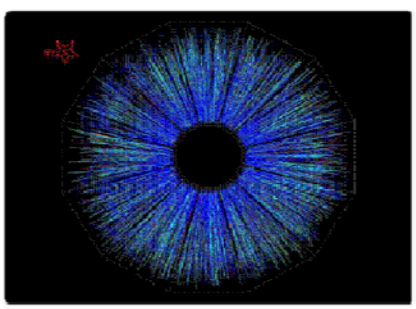
**The Scientific Challenges:**

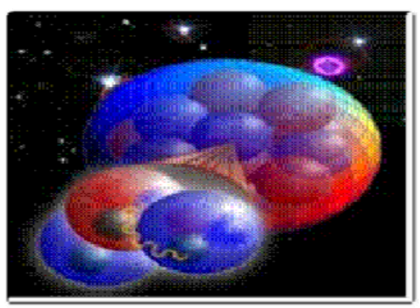
Understand:

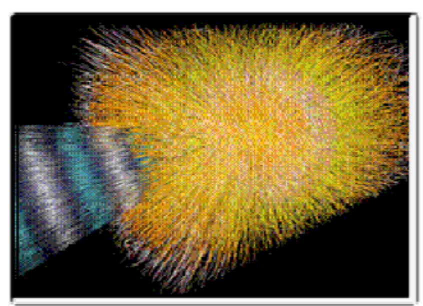
- The existence and properties of nuclear matter under extreme conditions, including that which existed at the beginning of the universe
- The exotic and excited bound states of quarks and gluons, including new tests of the Standard Model
- The ultimate limits of existence of bound systems of protons 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

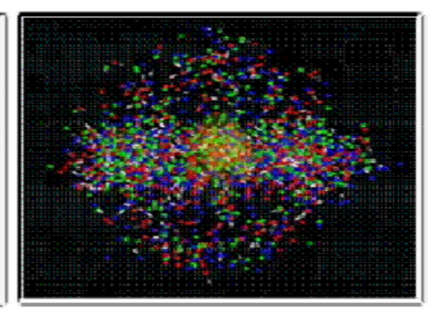
**FY 2012 Highlights:**

- 12 GeV CEBAF Upgrade to study exotic and excited bound systems of quarks and gluons and for illuminating the force that binds them into protons and neutrons.
- Design of the Facility for Rare Isotope Beams to study the limits of nuclear existence.
- Operation of three nuclear science user facilities (RHIC, CEBAF, ATLAS); closure of the Holifield Radioactive Ion Beam Facility at ORNL.
- Research, development, and production of stable and radioactive isotopes for science, medicine, industry, and national security.





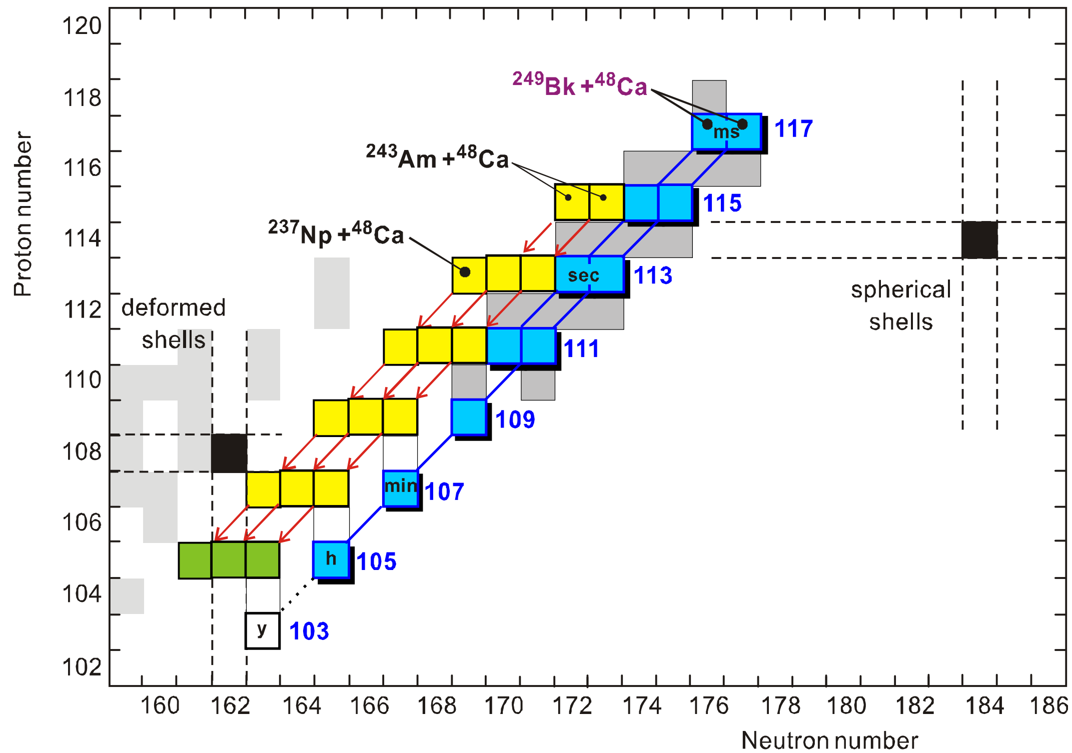


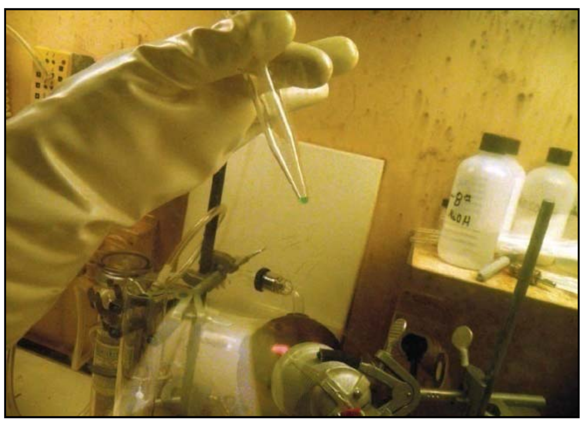


# Discovery of Element 117

A new super heavy element (SHE) with atomic number 117 was discovered by a Russian-U.S. team with the bombardment of a Berkelium target by 48-Ca. The existence and properties of SHEs address fundamental questions in physics and chemistry:

- How big can a nucleus be?
- Is there a "island of stability" of yet undiscovered long-lived heavy nuclei?
- Does relativity cause the periodic table to break down for the heaviest elements?

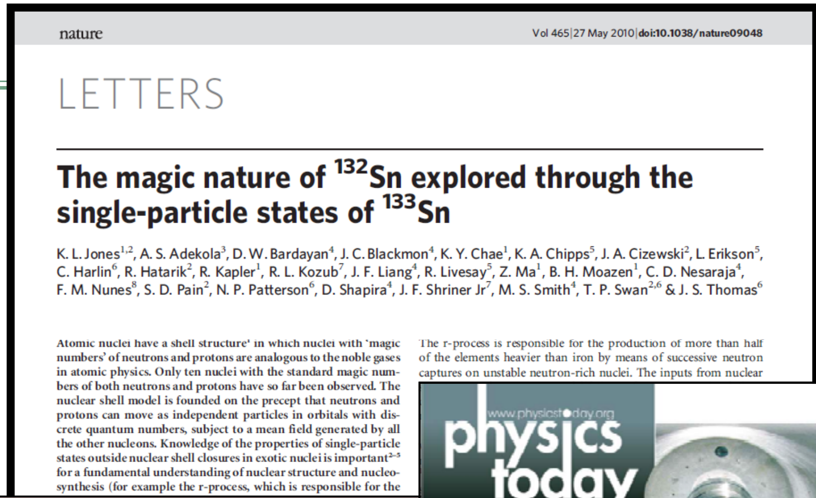


Rare short-lived 248-Bk was produced at HFIR and processed in Isotope Program hot cell facilities at ORNL to purify the 22 mg of target material used for the discovery of element 117.

- Experiment conducted at the Dubna Cyclotron (Russia) with an intense 48-Ca beam
- Berkelium target material produced and processed by the Isotopes Program at ORNL
- Detector and electronics provided by U.S. collaborators were used with the Dubna Gas-Filled Recoil Separator

# $^{132}$Sn shell structure



nature | Vol 465 | 27 May 2010 | doi:10.1038/nature09048

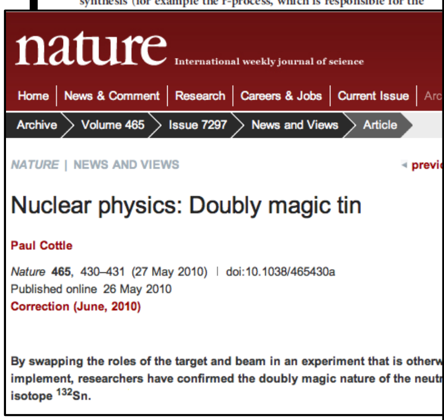
LETTERS

The magic nature of $^{132}$Sn explored through the single-particle states of $^{133}$Sn

K. L. Jones[1,2], A. S. Adekola[3], D. W. Bardayan[4], J. C. Blackmon[4], K. Y. Chae[1], K. A. Chipps[5], J. A. Cizewski[2], L. Erikson[5], C. Harlin[6], R. Hatarik[2], R. Kapler[1], R. L. Kozub[7], J. F. Liang[4], R. Livesay[5], Z. Ma[1], B. H. Moazen[1], C. D. Nesaraja[4], F. M. Nunes[8], S. D. Pain[2], N. P. Patterson[6], D. Shapira[4], J. F. Shriner Jr[7], M. S. Smith[4], T. P. Swan[2,6] & J. S. Thomas[6]

Atomic nuclei have a shell structure[1] in which nuclei with 'magic numbers' of neutrons and protons are analogous to the noble gases in atomic physics. Only ten nuclei with the standard magic numbers of both neutrons and protons have so far been observed. The nuclear shell model is founded on the precept that neutrons and protons can move as independent particles in orbitals with discrete quantum numbers, subject to a mean field generated by all the other nucleons. Knowledge of the properties of single-particle states outside nuclear shell closures in exotic nuclei is important[2–5] for a fundamental understanding of nuclear structure and nucleosynthesis (for example the r-process, which is responsible for the

The r-process is responsible for the production of more than half of the elements heavier than iron by means of successive neutron captures on unstable neutron-rich nuclei. The inputs from nuclear



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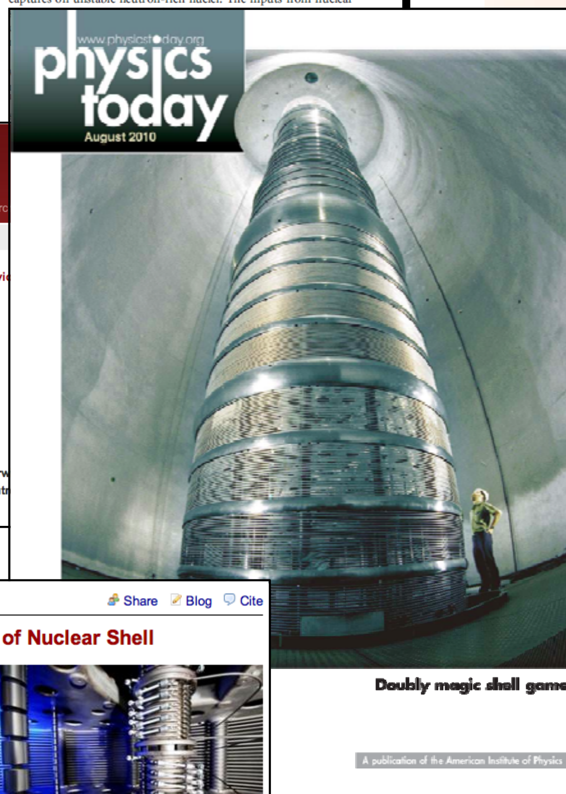
NATURE | NEWS AND VIEWS

Nuclear physics: Doubly magic tin

Paul Cottle

Nature 465, 430–431 (27 May 2010) | doi:10.1038/465430a
Published online 26 May 2010
Correction (June, 2010)

By swapping the roles of the target and beam in an experiment that is otherw implement, researchers have confirmed the doubly magic nature of the neutr isotope $^{132}$Sn.




Science News

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New 'Doubly Magic' Research Reveals Role of Nuclear Shell

ScienceDaily (June 1, 2010) — Researchers at the Department of Energy's Oak Ridge National Laboratory (ORNL), the University of Tennessee (UT) and six collaborating universities have performed an unprecedented nuclear reaction experiment that explores the unique properties of the "doubly magic" radioactive isotope of 132Sn, or tin-132.

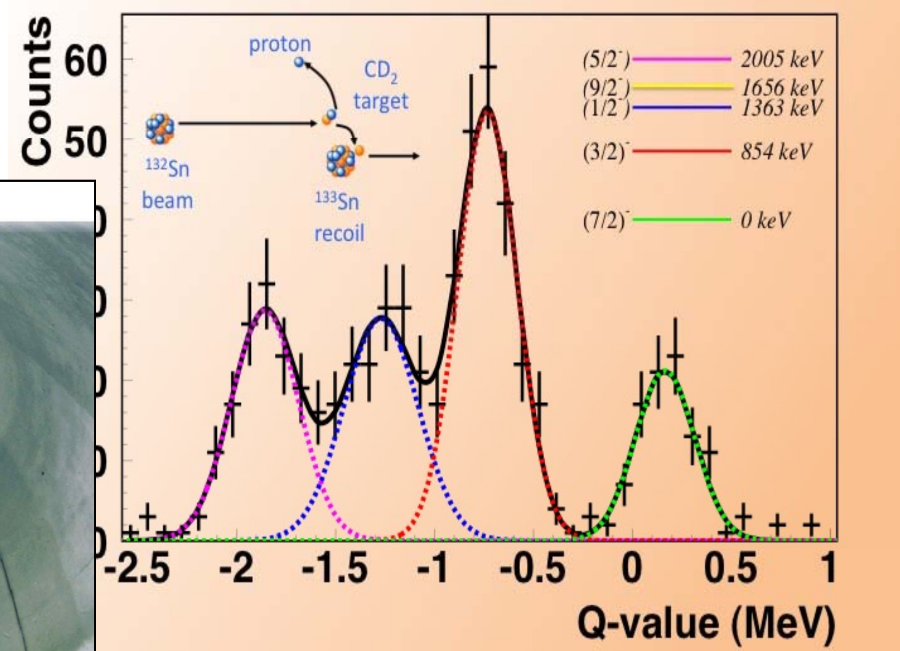
See Also:

Matter & Energy
- Weapons Technology
- Nuclear Energy
- Physics
- Chemistry
- Quantum Physics

The research, published in the journal Nature, is part of a broad scientific effort to understand nucleosynthesis, or the process by which the higher elements (those in the periodic table above iron) are created in the supernova explosions of stars. This research focused on the so-called r-process, responsible for the creation of about half of those

The Holifield facility enables scientists to produce beams of radioactive nuclei, then separate a particular isotope for experimentation with the world's most powerful electrostatic accelerator. (Credit: Image courtesy of DOE/Oak Ridge National Laboratory)

K. Jones et al., Nature 465, 454 (2010)

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  - December 2010
  - November 2010
  - October 2010
  - September 2010
  - August 2010
  - July 2010
  - June 2010

Short-lived tin is doubly magic

May 27, 2010 7 comments

Researchers in the US and UK have confirmed that a short-lived isotope of tin is the latest member in an exclusive club of "doubly magic" nuclei, a nuclear equivalent to the noble gases. This is only the seventh of these rigidly spherical nuclei to have its magical qualities measured. And the experiment could provide clues to how heavy elements are created in the supernova explosions of massive stars.

Other high-profile transfer studies in analysis/on the books

# $^{101}$Sn shell structure

Isotopes near $^{100}$Sn flout conventional wisdom

Darby et al., Phys. Rev. Lett. 105, 162502 (2010)

**Science News** Share Blog

## Isotope Near 'Doubly Magic' Tin-100 Flouts Conventional Wisdom

*ScienceDaily (Oct. 31, 2010)* — Tin may seem like the most unassuming of elements, but experiments performed at the Department of Energy's Oak Ridge National Laboratory are yielding surprising properties in extremely short-lived isotopes near tin-100's "doubly magic" nucleus.

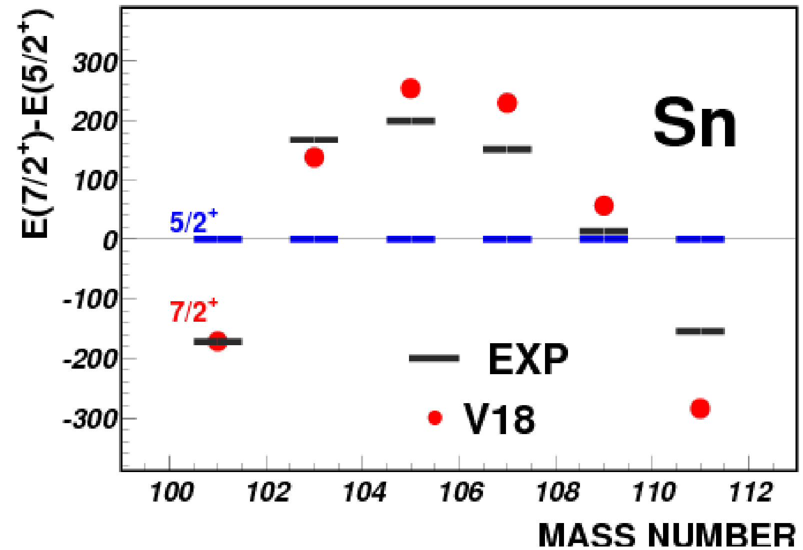
Experiments performed with the exotic nucleus tin-101, which has a single neutron orbiting tin-100's closed shell of 50 protons and 50 neutrons, indicate an unexpected reversal in the ordering of lowest states in the nucleus. The finding appears to violate a standard scenario offered by the nuclear shell model that has been the cornerstone for understanding the atomic nucleus for more than half a century.

**See Also:**

**Matter & Energy**
- Physics
- Spintronics
- Nuclear Energy
- Weapons Technology
- Quantum Physics
- Vehicles

**Reference**
- Tin








## Curious excitation of 'magic' isotope

THE ISOTOPES of tin (Sn) provide a perfect laboratory for studying a variety of nuclear properties at the limits of particle stability. The $^{100}$Sn isotope is particularly important as it has a so-called 'doubly magic' closed-shell nucleus, with 50 protons and 50 neutrons, which has helped physicists to develop the Nuclear Shell Model. Under this model it is expected that the ground-state spins of the semi-magic isotopes $^{101,103,105}$Sn will be identical, and dependent on which single-particle orbital has the lowest energy. Experimental data for known isotopes in this range have previously indicated no exceptions, but researchers at the Oak Ridge National Laboratory in the United States have found an unexpected result.

By measuring energy spectra in xenon-tellurium-tin alpha-decay chains, the team found that the spins of the ground state and the first excited state of $^{101}$Sn were reversed with respect to the heavier isotopes. The authors of the study, published in *Physical Review Letters*, explain that the inversion results from unusually strong pairing interactions between neutrons in the outer orbital and relatively small energy splitting between orbitals. This behaviour makes the proton-rich nuclei above $^{100}$Sn unique. Characterising their nature is essential for calibrating theoretical models and for predicting the properties of unmeasured nuclei. RJ

Issue 20, p. 4, http://www.bluesci.org/



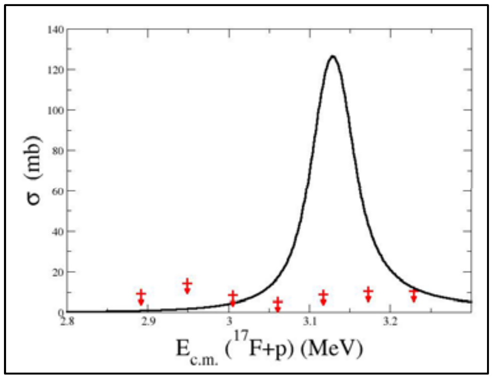


Next: $^{108}$Xe$\rightarrow$ $^{104}$Te $\rightarrow$$^{100}$Sn

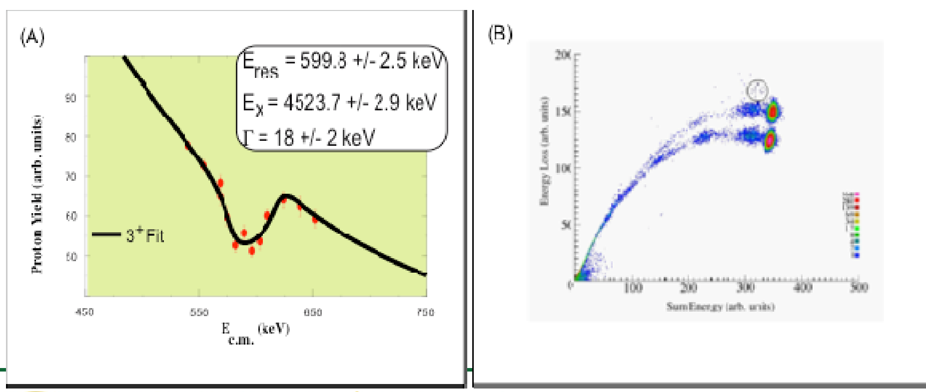
# Cosmic origin of the elements

Search for inelastic $^{17}$F+p scattering for a predicted resonance that could impact the $^{14}$O($\alpha$,p')$^{17}$F* reaction rate
Bardayan et al., PRC 81, 065802 (2010)

*Predicted resonance at 3.5 MeV was ruled out based on upper limits obtained.*




$^{17}$F(p,$\gamma$)$^{18}$Ne
K. Chipps et al., Phys. Rev. C 80, 065810 (2009)



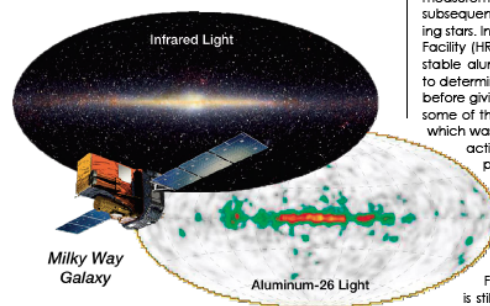

Production of galactic 26Al in novae
K. A. Chipps et *al.*, Phys. Rev. C 82, 045803 (2010)

Nuclear Physics **Highlights**

## Exploring the Cosmic Origin of the Elements

Where do all the elements that make up our bodies and our world come from?

For most of recorded history, the answer to this question has been the stuff of speculation, if not myth. Today DOE scientists, in concert with their colleagues around the world, synergistically combine cutting edge measurements in nuclear accelerator labs with computer simulations and satellite observations to probe the mysteries of our Galaxy and the Universe.

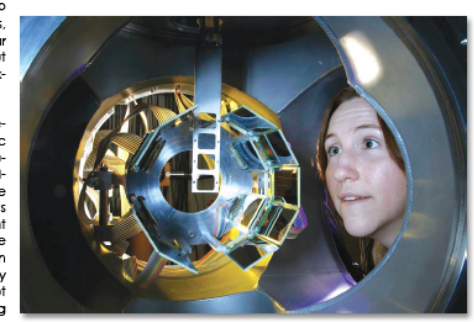



As a consequence of their work, we now know some answers to the "elements puzzle." Some of the elements, for example, were formed in the Big Bang, when the universe was created. Others were cooked up in the seething maelstrom of stars. Still others, we think, are created in cataclysmic stellar explosions, such as supernovae or novae. But just how much material is synthesized in exploding stars is still a mystery.

To address this, we launch satellites with special "eyes" to capture traces of these cosmic detonations and try to devise explosion simulations that match their snapshots. A magnificent example of this took place ninety-five thousand miles above Earth, where NASA's Compton Gamma Ray Observatory spent about 10 years gathering data, not in visible light but in "aluminum-26 light" which, when coalesced into a detailed map of our galaxy (the **figure above**), revealed numerous hot spots. The lumpy distribution, representing about three solar masses of radioactive aluminum-26, is inconsistent with some models of how the elements are created. Whatever created this aluminum-26, it must have happened recently—within the last million years or so—because this exotic aluminum decays into magnesium in that time, emitting energy in the form of gamma rays—the source of the hot spots.

To make sense of these and related discoveries, an international effort has been launched to make laboratory measurements of the nuclear reactions that create, and subsequently destroy, this unusual aluminum in exploding stars. In 2009 at DOE's Holifield Radioactive Ion Beam Facility (HRIBF) in Oak Ridge, Tennessee, a beam of unstable aluminum-26 bombarded a target of hydrogen to determine how fast this exotic aluminum is burned up before giving off its special light. The **photo below** shows some of the sophisticated detectors used for this study, which was a search for "sweet spots" in the nuclear reaction that would destroy more aluminum than previously thought. When the HRIBF results are combined with a complementary measurement at the TRIUMF facility near Vancouver, Canada, and results from other facilities, we will get a better handle on exactly what this map is telling us about exploding stars.

For all that we have discovered so far, there is still much to learn. For example, we know very little about how elements heavier than iron came into being. DOE's Facility for Rare Isotope Beams (aka FRIB), planned for nearly a decade, will give us the ability to study this right here on Earth to find additional pieces in the elements puzzle.





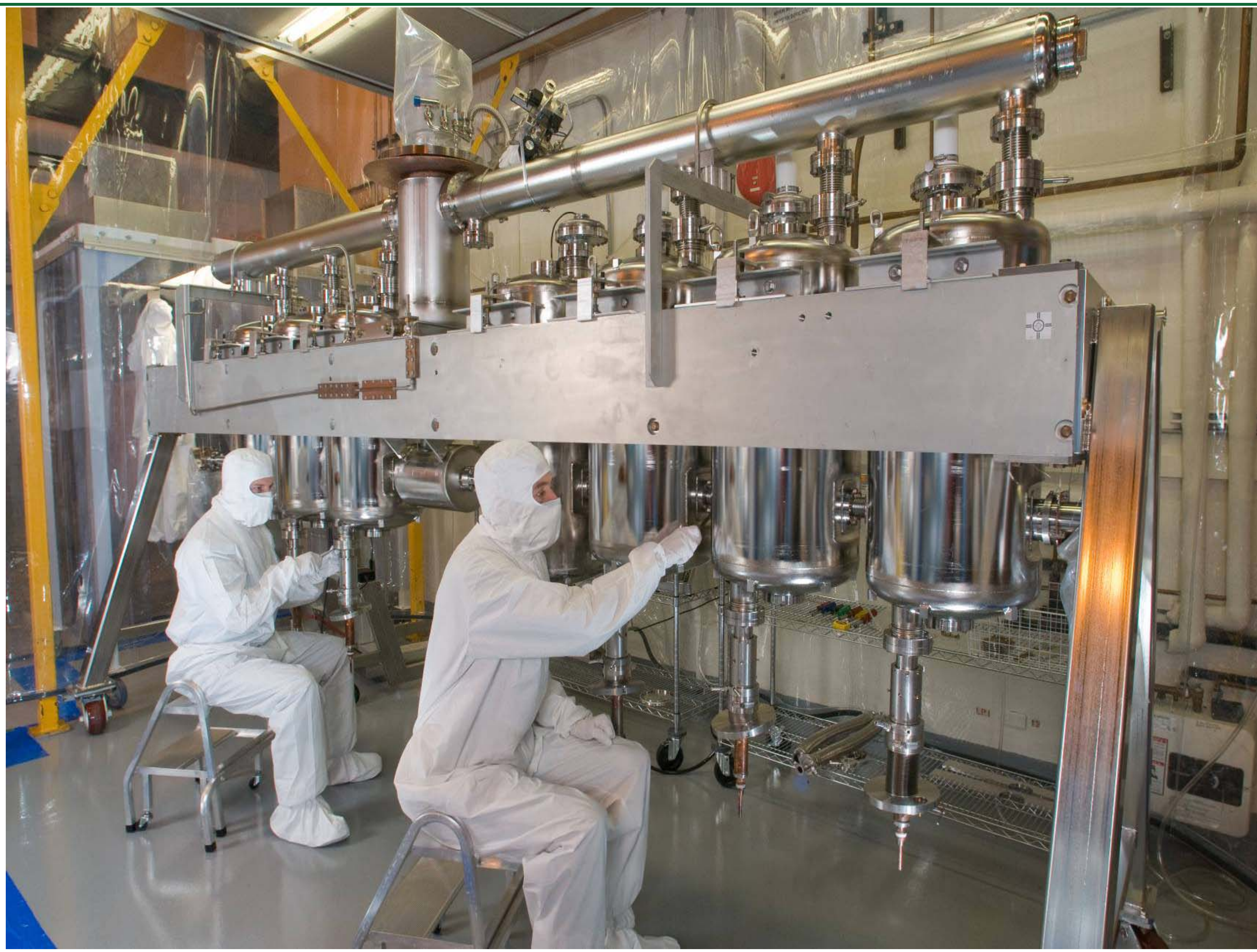
Unique equipment: DRS, ORRUBA, …

# Comments on closure of HRIBF as a National User Facility

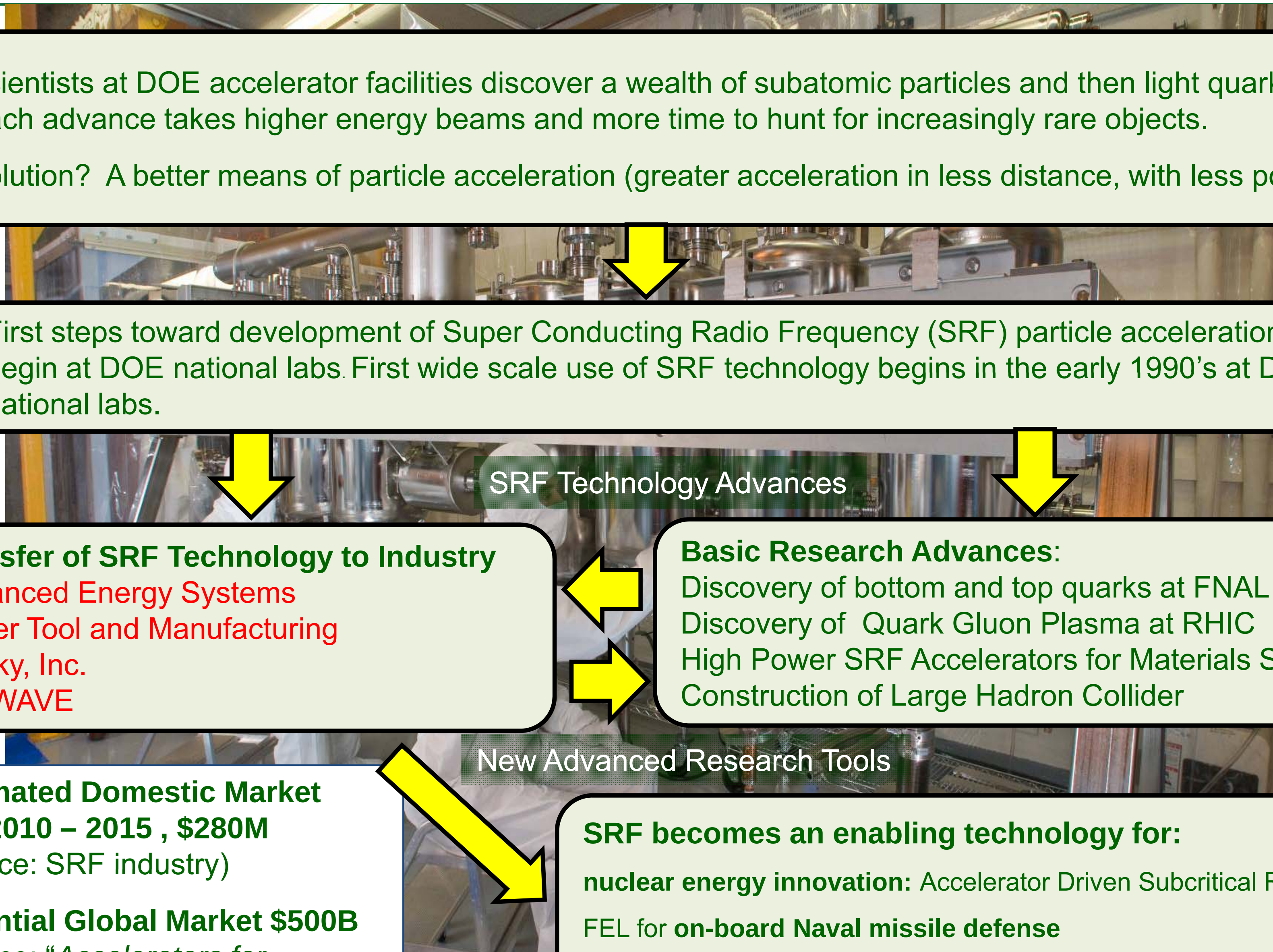
There will be more discussion of HRIBF in the FY 2012 budget but to address some points:

- The issue is **not** the quality of the physics, the physicists, or the technical staff
- The strategy is to provide the nuclear structure and nuclear astrophysics subfield with the best machine in the world within the next 6-7 years.
- To do that NP will be investing well over $500M in nuclear structure and nuclear astrophysics
- There is every intention to continue to utilize NSAC to address important questions before the field (current charge on neutron science, for example)
- There is every intention to continue to leverage our university centers of excellence and smaller facilities
- This closure will impact science opportunities and result in the loss of some unique capability before FRIB turns on. That is a challenge we have to deal with
- This subfield is not the only one impacted by the major construction for medium energy and nuclear structure/astrophysics during this decade
- The decision to close HRIBF and the decision to provide funds to continue dewatering at DUSEL to protect NP's interest in underground science are not causally related

# Basic Research – Super Conducting Radio Frequency (SRF) particle acceleration



# The Basic Research – Advanced Technology Products "Tango" in NP and HEP



Scientists at DOE accelerator facilities discover a wealth of subatomic particles and then light quarks. Each advance takes higher energy beams and more time to hunt for increasingly rare objects.

Solution? A better means of particle acceleration (greater acceleration in less distance, with less power)

First steps toward development of Super Conducting Radio Frequency (SRF) particle acceleration begin at DOE national labs. First wide scale use of SRF technology begins in the early 1990's at DOE national labs.

SRF Technology Advances

**Transfer of SRF Technology to Industry**
Advanced Energy Systems
Meyer Tool and Manufacturing
Sciaky, Inc.
NIOWAVE

**Basic Research Advances**:
Discovery of bottom and top quarks at FNAL
Discovery of Quark Gluon Plasma at RHIC
High Power SRF Accelerators for Materials Science
Construction of Large Hadron Collider

New Advanced Research Tools

**Estimated Domestic Market For 2010 – 2015 , $280M**
(source: SRF industry)

**Potential Global Market $500B**
(source: "*Accelerators for America's Future*")

**SRF becomes an enabling technology for:**

**nuclear energy innovation:** Accelerator Driven Subcritical Reactors

FEL for **on-board Naval missile defense**

Integrated **Standoff Inspection System for ships and cargo**

# A budding industry borne of technology developed at SC Labs for basic science

New Jobs, Increasing Revenues, International U.S. Leadership

**Advanced Energy Systems (founded 1998)**
**Medford, New York**

- SRF **revenues doubled** from 2009-2010
- **Close to 20 new hires** in 2010

**Meyer Tool and Manufacturing (SRF work started1995)**
**Oak Lawn, Illinois**

- Anticipate **25% of sales from SRF in 2012**
- SRF sales are presently 25% of the backlog and the backlog is one half of the total sales
- Expected growth in sales is 3-5%
- Anticipate hiring **42 new employees** including 5 engineers and 32 manufacturing staff
- **Present staff is 38** employees

**NIOWAVE (founded 2005)**
**Lansing, Michigan**

- Revenues of ~$10M in 2010
- **Workforce expected to triple from 50 – 150**
- Second manufacturing facility planned

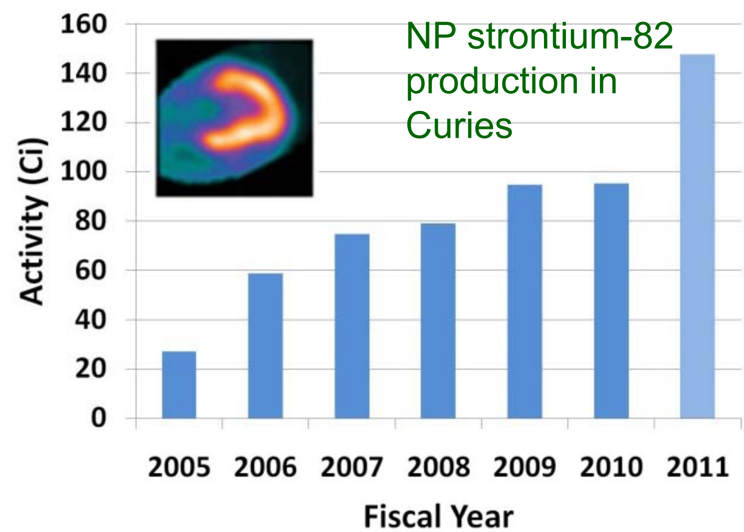
Highly optimized particle acceleration cavity

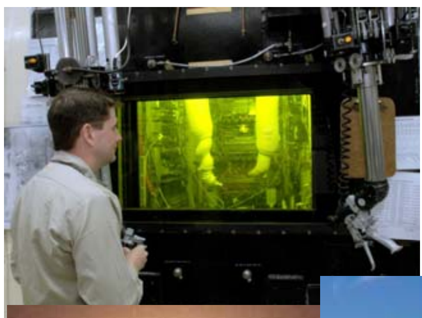
Current market is modest. Potential market is very large.

# Radioisotope Production for Research and Commercial Applications: the result of "know-how" from the basic research program

NP is Increasing strontium-82 (**$Sr^{82}$**) production for cardiac imaging in response to molybdenum-99 supply challenges

- **200,000 patients per year in U.S.**
- **~ $300,000,000 in reimbursable procedures**
- **DOE supplies ~ 75% of domestic $Sr^{82}$ market**



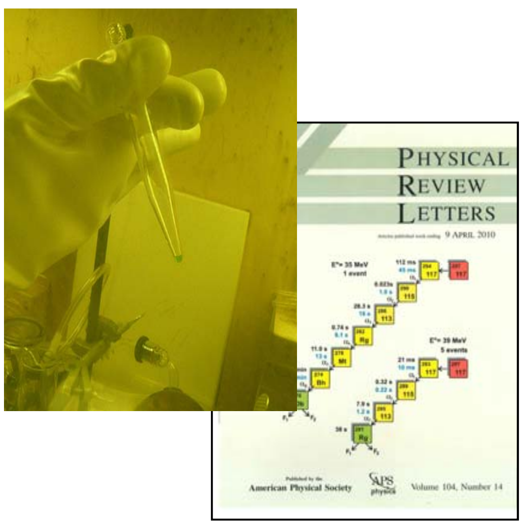
Californium-252 production for oil and gas exploration, nuclear fuels, homeland security, and nuclear science research experiments

- DOE supplies 97% of domestic market; **californium supply is critical** to oil and gas revenues and nuclear reactor industries
- Domestic oil and gas production **employs 210,000 Americans** and 920,000 jobs. **Contributes ~$100 billion to the U.S. economy**
- 104 domestic nuclear reactors produced ~ 20% of total electricity in U.S. **Contributes ~$240 billion to the U.S. economy**

# Radioisotope Production for Research and Commercial Applications: the result of "know-how" from the basic research program

## Basic Research Supported

- NP is providing rare isotopes for research not previously available
- NP is the sole provider of research isotopes for super heavy element discovery research
- 22 mg of berkelium-249 produced as by- product of californium production for collaborative experiment between U.S. and Russia leading to the discovery of element 117
- NP is supporting production of 25 mg of Bk-249 for a follow-up search to discover element 119 and 120




Bk-249, contained in the greenish fluid in the tip of the vial, was used to discover element 117.

## Applied Research Supported

- ~$6 M invested in development of production technologies for alpha-emitting medical radio-nuclides
- Promising R&D for treating cancers affecting hundreds of thousands of lymphoma, leukemia, breast, and prostate cancer patients
- NP developing cost-effective production strategy to support clinical trials

NP is developing Ac-225 production capability in support of testing to demonstrate the effective of this alpha-emitting isotope for cancer therapy.

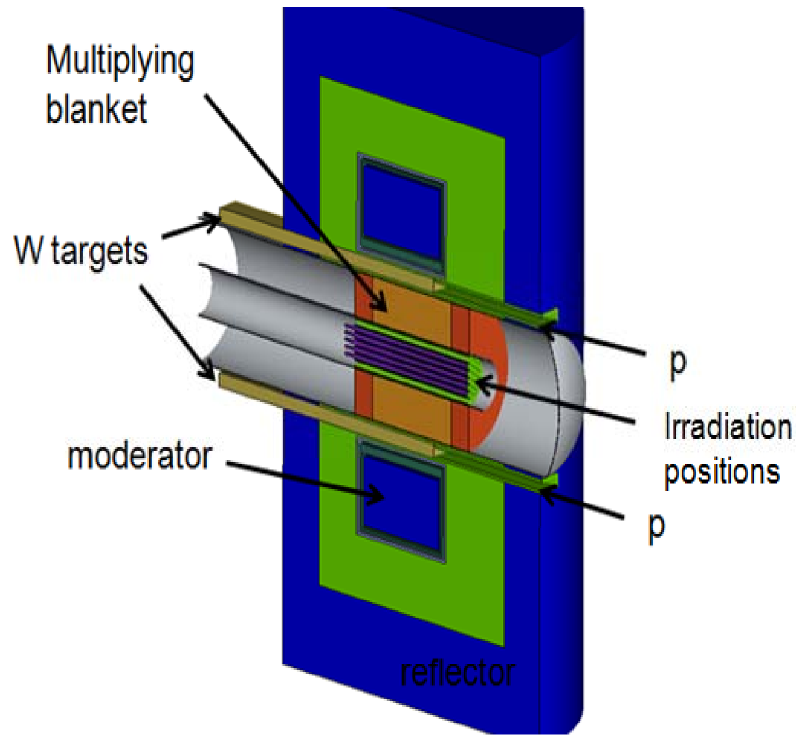
## SRF is an enabling technology for Accelerator Driven Systems (ADS)

- Subcritical reactor driven by an accelerator-based neutron source
- **Potential advantages**
  - Safety

    accelerator off = reactor off
  - Non-Proliferation

    reduced use of special nuclear materials
  - Waste

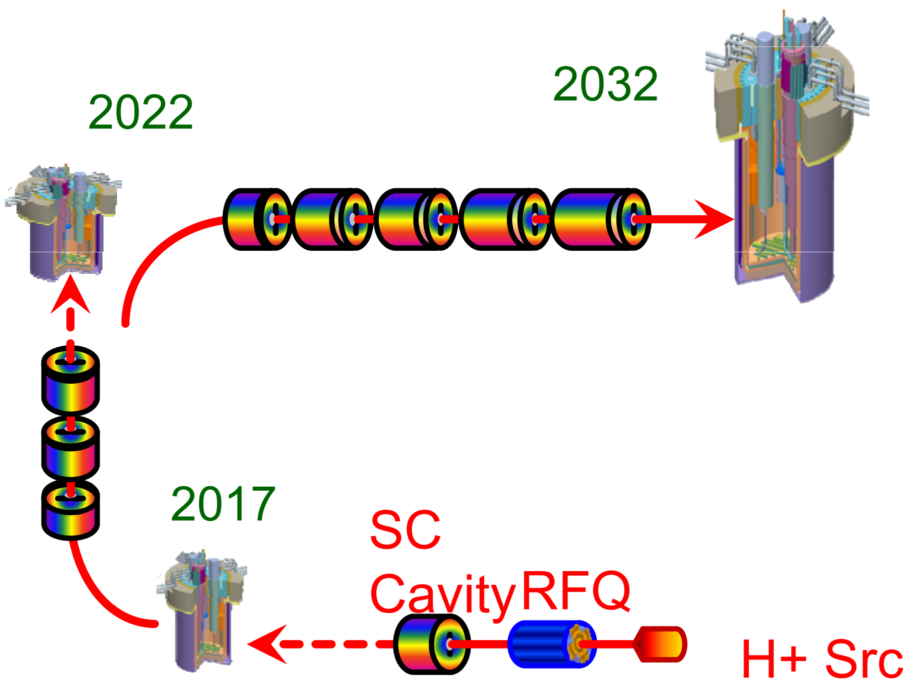
    transmutation; generation of shorter-lived waste products
- **Many proposed applications**
  - Waste transmutation
  - Energy generation
  - Isotope production
  - Fuel testing



# International Interest in Potential SRF-Enabled Nuclear Energy Innovation "Game Changer"

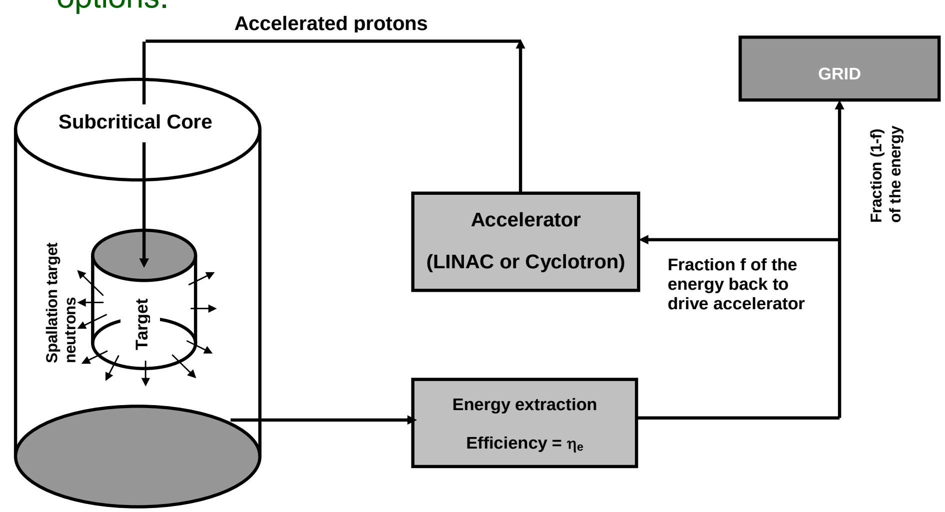
**W. Zhan, VP of Chinese Academy of Science**
**Chinese ADS Plan (November 2010):**

- ADS 4 Mega-watt Test Setup: 2017
- ADS 80-100 Mega-watt Experimental Facility 2022
- ADS 1000 Mega-watt Demo facility 2032




**S. Bannerjee, Sec. Indian Dept. Of Atomic Energy (DAE)**
**Indian ADS Plan (October 2010)**

- ADS applications have potential to resolve the problems of nuclear waste and thorium utilization as nuclear fuel to meet energy needs for centuries.
- New technologies for proton accelerator and spallation target need specific R&D programs.
- India would pursue R&D to implement ADS for sustainable nuclear power program.
- Ongoing ADS and reactor developments are first step in that direction.
- India would like to invite and participate international R&D activities- on accelerator, spallation target and fuel cycle options.



**Military Tech Breakthrough Laser Could Revolutionize Navy's Weaponry**
Published January 20, 2011
FoxNews.com

**“Zap They’re Dust”**
The Virginian Pilot
January 21, 2011

“Navy Makes Strides On Goal to Outfit Ships With Anti-Missile Lasers”

“..The free-electron laser project began as a science and technology program at the Office Of Naval Research in the 1980’s **and matured into a 14 kilowatt prototype that was developed at the Thomas Jefferson National Accelerator Facility in Newport News**. Work began last year on a 100 kilowatt prototype….”

# Homeland Security, National Defense, and Nuclear Applications Innovation: the result of "know-how" gained from the basic research program

**Muon Tomography**:

A cosmic-ray induced tracking technology that produces 3-D tomographic images of vehicles and their contents. Suitable for screening for hidden nuclear weapons components at ports of entry.

- This technology has been transferred to Decision Sciences Corporation.
- Large units are now under construction for customer's installation.
- Follow-on applications for commercial application under investigation.
- Potentially a very large market.
- Non-NP program support, but capability created as a result of NP research.

**Proton Radiography**:

NNSA funded study of dynamic phenomena of importance to nuclear weapons, including high explosives performance, material damage, and the performance of materials under extreme pressures.

- This capability was invented by scientists trained in the NP program.
- Scientists partially funded by NP participate in this program today.

**NP National Nuclear Data Center:**

Compiles and verifies data important for well logging, neutron therapy, and development of fast reactors.

- 2.6 million data retrievals by business, government, and research in 2010.

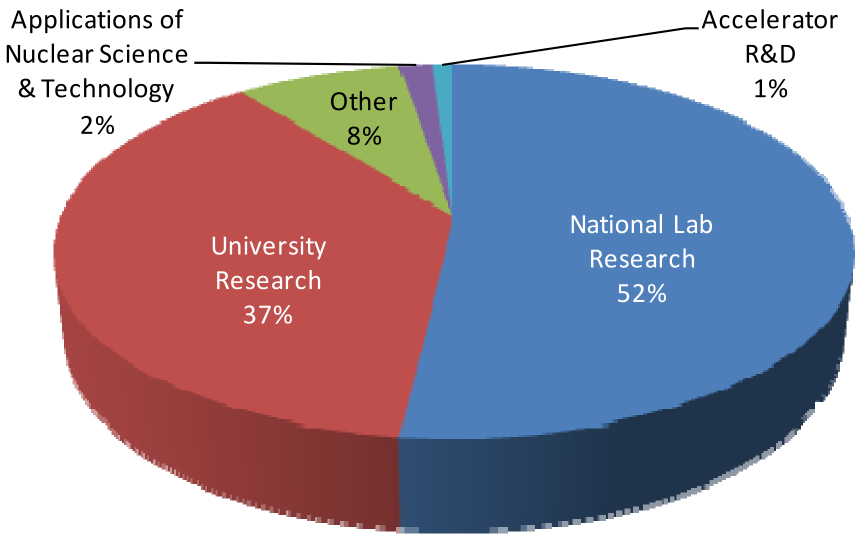
# Additional Information

# FY 2012 Congressional Request by Function

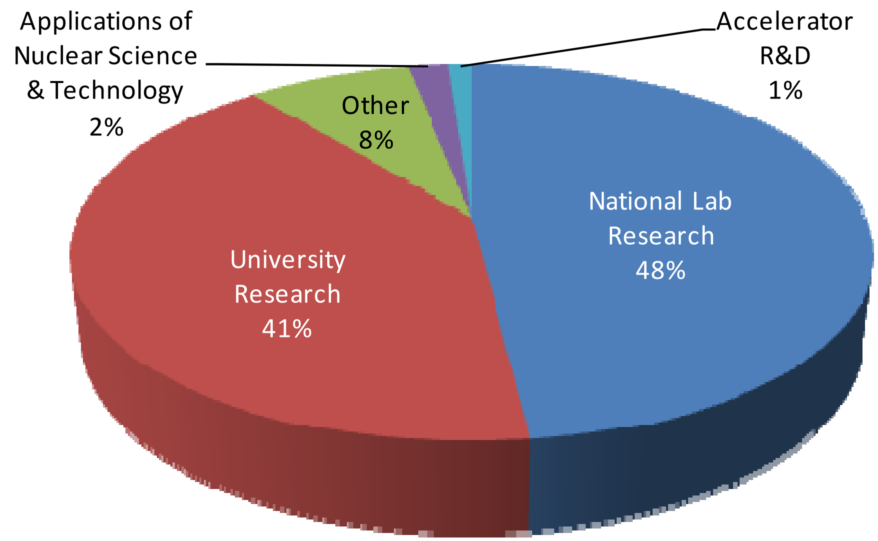
(dollars in thousands)

| NUCLEAR PHYSICS | FY 2010 Approp. | FY 2010 Approp. with SBIR/STTR | FY 2012 Request | FY 2010 to FY 2012 Change | | FY 2010 with SBIR/STTR to FY 2012 Change | |
|---|---|---|---|---|---|---|---|
| | | | | $ | % | $ | % |
| **Research** | | | | | | | |
| University | 78,366 | 78,366 | 75,408 | -2,958 | -3.8% | -2,958 | -3.8% |
| National Laboratory | 92,688 | 92,688 | 107,084 | +14,396 | +15.5% | +14,396 | +15.5% |
| Other (incl SBIR/STTR) | 4,311 | 16,851 | 18,109 | +13,798 | +320.1% | +1,258 | +7.5% |
| **Total Research** | **175,365** | **187,905** | **200,601** | **+25,236** | **+14.4%** | **+12,696** | **+6.8%** |
| **Facility Operations** | | | | | | | |
| RHIC/BNL | 157,195 | 157,195 | 164,610 | +7,415 | +4.7% | +7,415 | +4.7% |
| CEBAF/TJNAF | 83,327 | 83,327 | 83,930 | +603 | +0.7% | +603 | +0.7% |
| HRIBF/ORNL | 17,080 | 17,080 | 6,821 | -10,259 | -60.1% | -10,259 | -60.1% |
| ATLAS/ANL | 16,216 | 16,216 | 16,762 | +546 | +3.4% | +546 | +3.4% |
| Isotope Facilites | 16,116 | 16,116 | 15,895 | -221 | -1.4% | -221 | -1.4% |
| Other (88"/ORELA/DUSEL) | 4,253 | 4,253 | 9,495 | +5,242 | +123.3% | +5,242 | +123.3% |
| **Total Facility Operations** | **294,187** | **294,187** | **297,513** | **+3,326** | **+1.1%** | **+3,326** | **+1.1%** |
| **Projects** | | | | | | | |
| Major Items of Equipment | 15,998 | 15,998 | 6,186 | -9,812 | -61.3% | -9,812 | -61.3% |
| Facility for Rare Isotope Beams | 12,000 | 12,000 | 30,000 | +18,000 | +150.0% | +18,000 | +150.0% |
| Construction (12 GeV) | 20,000 | 20,000 | 66,000 | +46,000 | +230.0% | +46,000 | +230.0% |
| **Total Projects** | **47,998** | **47,998** | **102,186** | **+54,188** | **+112.9%** | **+54,188** | **+112.9%** |
| Other (BNL GPE) | 4,910 | 4,910 | 5,000 | +90 | +1.8% | +90 | +1.8% |
| **TOTAL, NUCLEAR PHYSICS** | **522,460** | **535,000** | **605,300** | **+82,840** | **+15.9%** | **+70,300** | **+13.1%** |

# FY 2012 Congressional Request Nuclear Physics Research



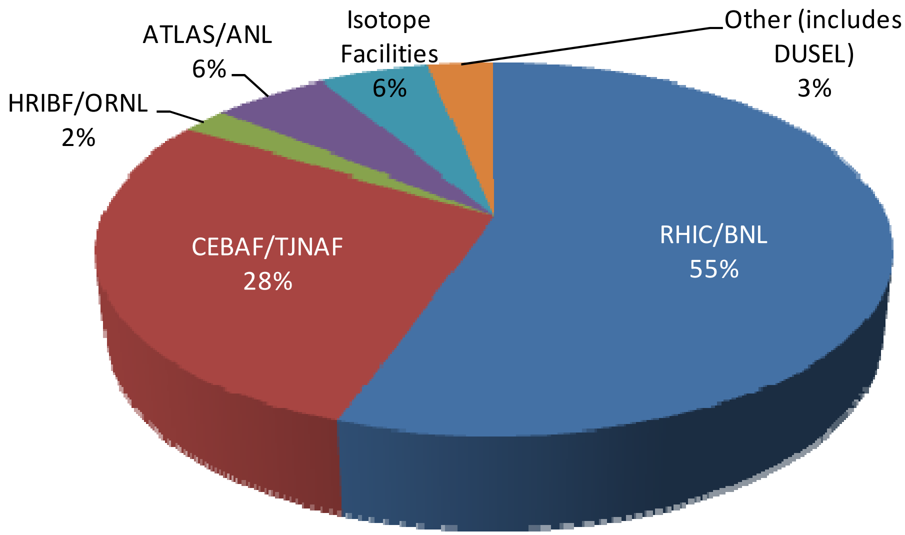

**FY 2012 Congressional Request**
**Total = $200.6M**



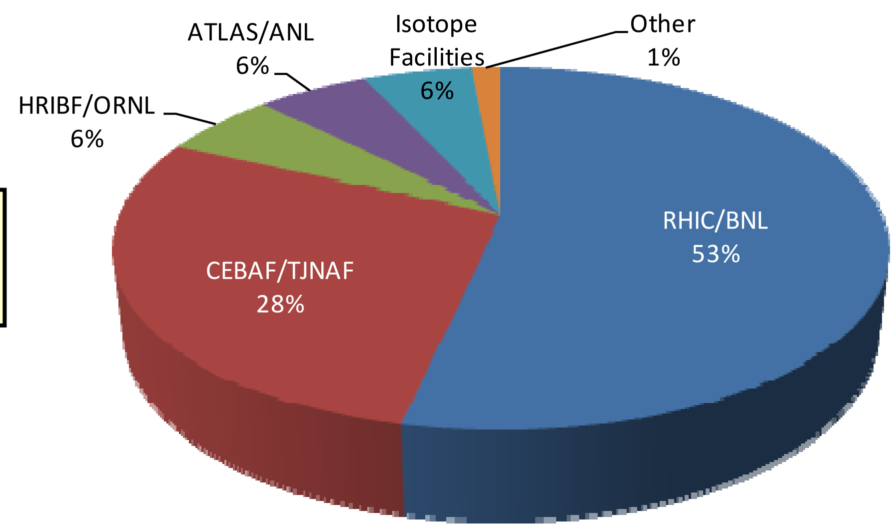

**FY 2010 Appropriation**
**Total = $187.9M**

*Other includes SBIR/STTR*

# FY 2012 Congressional Request Nuclear Physics Facility Operations




**FY 2012 Congressional Request**
**Total = $297.5M**




**FY 2010 Appropriation**
**Total = $294.2M**