Perspectives and News from Nuclear Physics

Nuclear Science Advisory Committee Meeting
Crystal City Marriott
June 30- July 1, 2011

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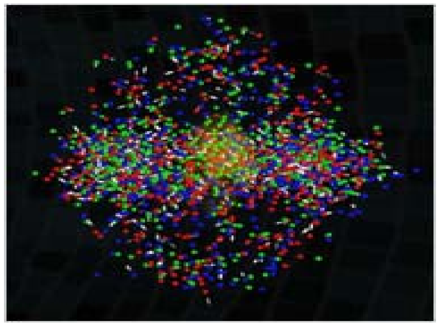
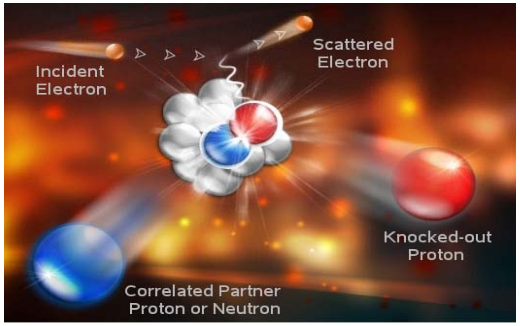
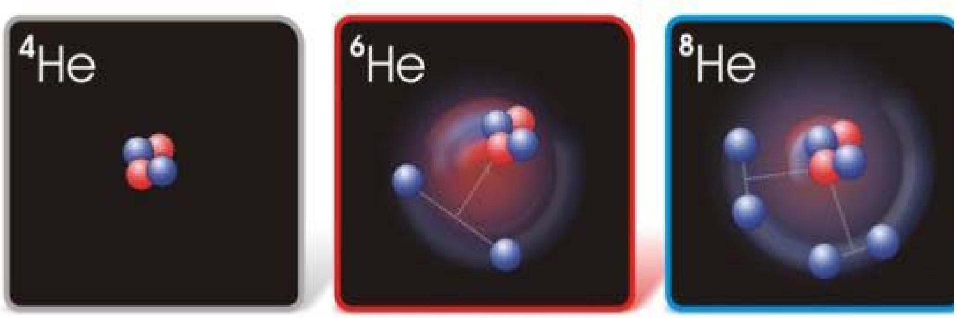
Office of Science, U.S. Department of Energy

The Vision of the Office of Nuclear Physics

- To enable U.S. world leadership in discovery science illuminating the properties of nuclear matter in all of its manifestations
- To provide the tools necessary for scientific and technical advances which will lead to new knowledge, new competencies, and groundbreaking innovation and applications
- To make strategic investments in facilities and research to provide the U.S. with the premier facilities in the world by the end of the decade for research on:
  - New states of matter 100 times more dense than “normal’ nuclear matter at the Relativistic Heavy Ion Collider
  - The force which binds quarks and gluons in protons and neutrons at the 12 GeV Continuous Electron Beam Accelerator Facility
  - The limits of nuclear existence for neutron and proton rich nuclei at the Facility for Rare Isotope Beams and the Argonne Tandem Linac Accelerator System
  - Innovative, effective and reliable isotope production with a new dedicated isotope facility







Nuclear Physics

Discovering, exploring, and understanding all forms of nuclear matter

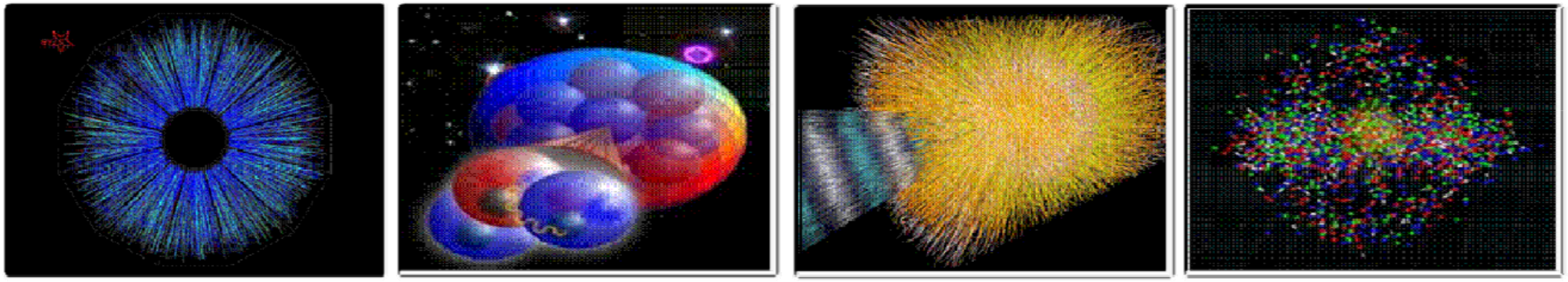
The Scientific Challenges:

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.



Nuclear Physics
FY 2012 Congressional Request

	FY 2010 Approp.	FY 2010 Approp. with SBIR / STTR	FY 2011 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	127,730	130,380	+8,267	+6.8%	+2,899	+2.3%
Heavy Ion	205,063	210,725	208,619	219,984	+14,921	+7.3%	+9,259	+4.4%
Low Energy	116,216	117,642	105,153	126,536	+10,320	+8.9%	+8,894	+7.6%
Theory	39,952	39,952	42,924	42,166	+2,214	+5.5%	+2,214	+5.5%
Isotope Program	19,116	19,200	19,760	20,234	+1,118	+5.8%	+1,034	+5.4%
Construction	20,000	20,000	35,928	66,000	+46,000	+230.0%	+46,000	+230.0%
Total	**522,460**	**535,000**	**540,114**	**605,300**	**+82,840**	**+15.9%**	**+70,300**	**+13.1%**

FRIB +$18M

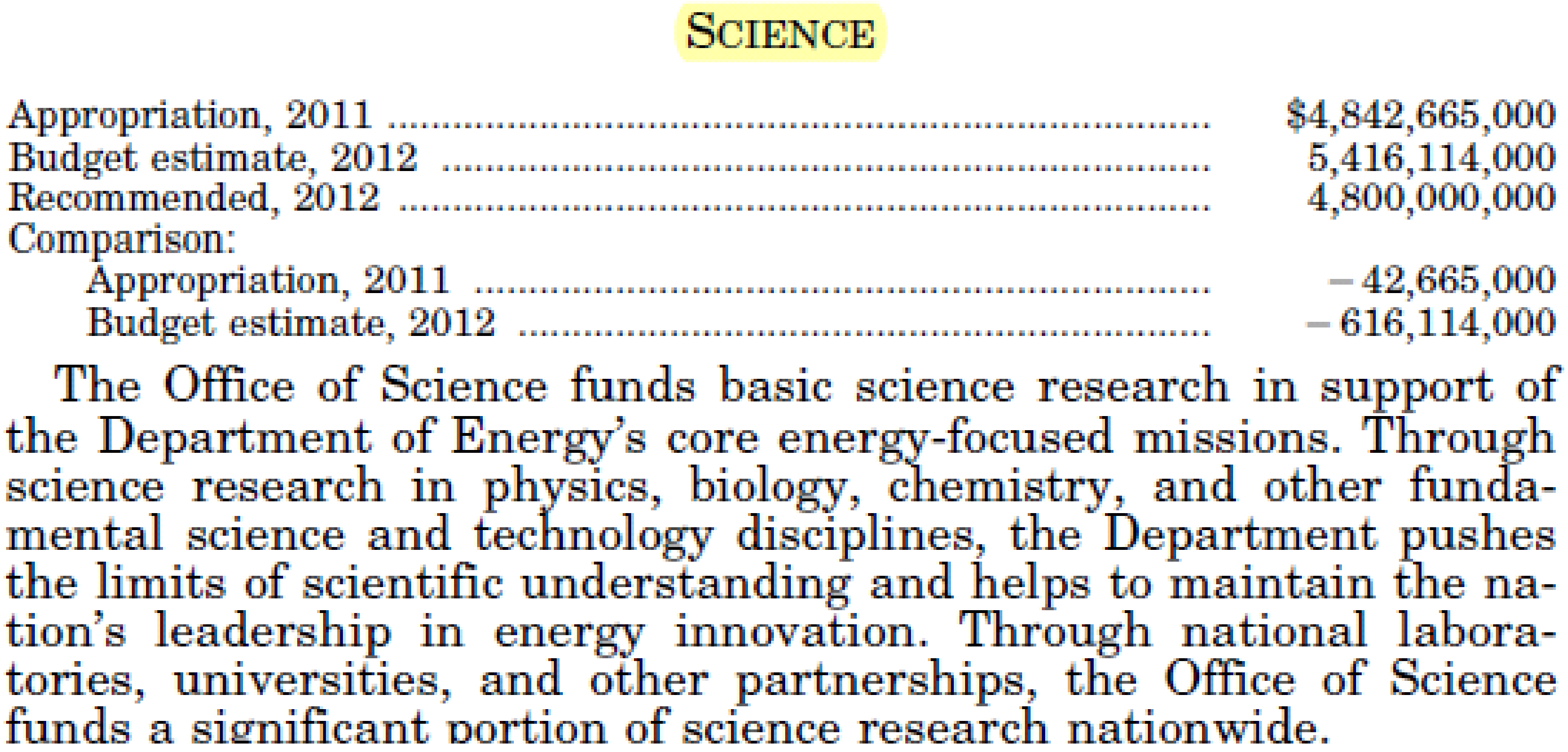
12 GeV Upgrade +$46M

- The FY 2012 budget request is dominated by continued support, as planned, for the two highest priorities in the Nuclear Science Community. **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 ($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** ▪ RHIC – 24 weeks of operations at increased luminosity (+$7.4M) ▪ CEBAF – 27 weeks of operations, maximum possible with 12 GeV installation schedule (+$0.6M) ▪ ATLAS – 39 weeks, including commissioning of new accelerator components (+$0.6M) ▪ 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; and isotope production research (a redistribution of efforts previously categorized as operations. 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** ▪ **STAR HFT** – ramps up per planned profile for RHIC high luminosity run in FY 2013 (+$1.9M) ▪ **nEDM** – slowed relative to project plans approved at CD-1 (-$3.4M) ▪ Funding completion for **ALICE EMCal, CUORE** and **GRETINA** per planned profiles (-$8.3M)	- 9,812
TOTAL NUCLEAR PHYSICS	**+$70,300**

House Mark Language June 2011

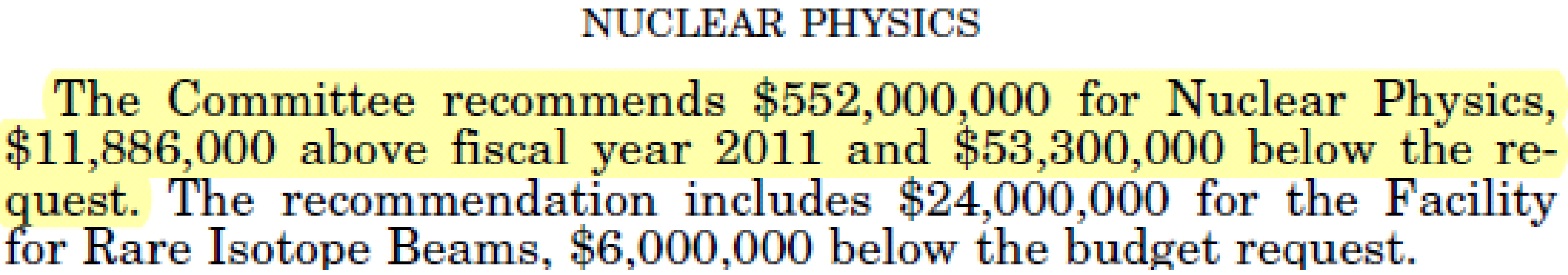


SCIENCE

Appropriation, 2011	$4,842,665,000
Budget estimate, 2012	5,416,114,000
Recommended, 2012	4,800,000,000
Comparison:	
Appropriation, 2011	−42,665,000
Budget estimate, 2012	−616,114,000

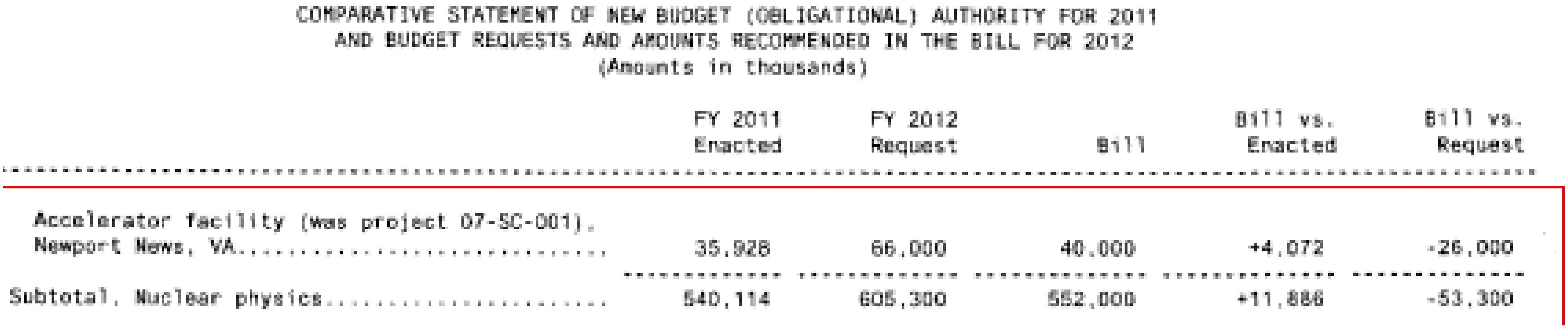
The Office of Science funds basic science research in support of the Department of Energy's core energy-focused missions. Through science research in physics, biology, chemistry, and other fundamental science and technology disciplines, the Department pushes the limits of scientific understanding and helps to maintain the nation's leadership in energy innovation. Through national laboratories, universities, and other partnerships, the Office of Science funds a significant portion of science research nationwide.

House Mark Language June 2011



NUCLEAR PHYSICS

The Committee recommends $552,000,000 for Nuclear Physics, $11,886,000 above fiscal year 2011 and $53,300,000 below the request. The recommendation includes $24,000,000 for the Facility for Rare Isotope Beams, $6,000,000 below the budget request.



COMPARATIVE STATEMENT OF NEW BUDGET (OBLIGATIONAL) AUTHORITY FOR 2011
AND BUDGET REQUESTS AND AMOUNTS RECOMMENDED IN THE BILL FOR 2012
(Amounts in thousands)

	FY 2011 Enacted	FY 2012 Request	Bill	Bill vs. Enacted	Bill vs. Request
Accelerator facility (was project 07-SC-001), Newport News, VA	35,928	66,000	40,000	+4,072	-26,000
Subtotal, Nuclear physics	540,114	605,300	552,000	+11,886	-53,300

The bill recommends the following changes in program budgets from this year:

•Fusion Energy Sciences:	Up 8.1 percent
•Nuclear Physics:	Up 2.2 percent
•Advanced Scientific Computing:	Up 1.2 percent
•Basic Energy Sciences:	Up 0.6 percent
•High Energy Physics:	Up 0.2 percent
•Biological and Environmental Research:	Down 10.6 percent

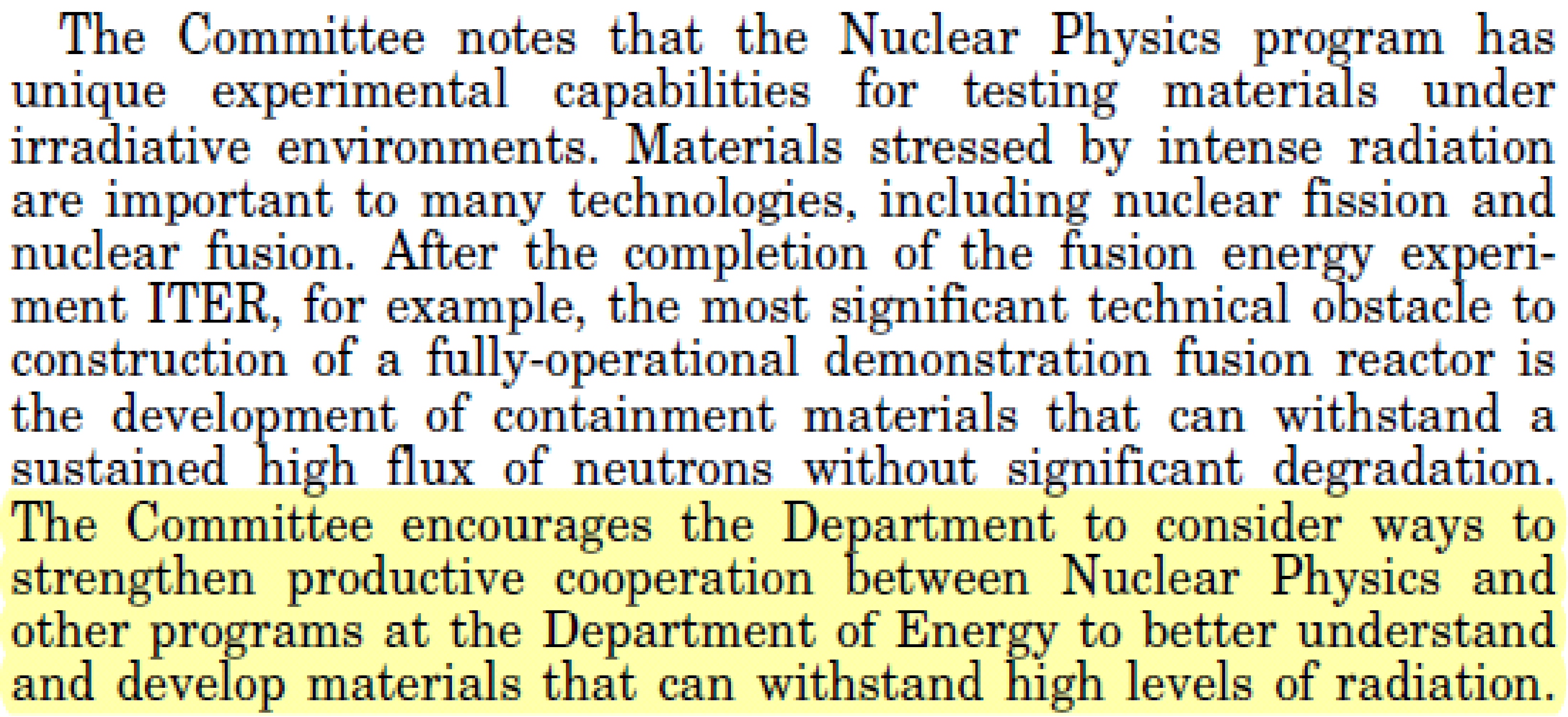
House Mark Language June 2011

Office of Science
FY 2012 Funding Status
(budget authority in thousands of dollars)

		FY 2012					
	FY 2011 Approp. [a/]	Request	House Committee	House vs. FY 2011		House vs. Request	
Advanced Scientific Computing	421,997	465,600	427,093	+5,096	+1.2%	-38,507	-8.3%
Basic Energy Sciences	1,678,195	1,985,000	1,688,145	+9,950	+0.6%	-296,855	-15.0%
Biological and Environmental Research	611,823	717,900	547,075	-64,748	-10.6%	-170,825	-23.8%
Fusion Energy Sciences	375,462	399,700	406,000	+30,538	+8.1%	+6,300	+0
High Energy Physics	795,420	797,200	797,200	+1,780	+0.2%	—	—
Nuclear Physics	540,114	605,300	552,000	+11,886	+2.2%	-53,300	-8.8%
Workforce Development	22,600	35,600	17,849	-4,751	-21.0%	-17,751	-49.9%
Science Lab Infrastructure	125,748	111,800	103,487	-22,261	-17.7%	-8,313	-7.4%
Safeguards and Security	83,786	83,900	83,900	+114	+0.1%	—	—
Science Program Direction	202,520	216,863	180,000	-22,520	-11.1%	-36,863	-17.0%
Subtotal, Science	4,857,665	5,418,863	4,802,749	-54,916	-1.1%	-616,114	-11.4%
Use of prior year balances	-15,000	-2,749	-2,749	+12,251	+81.7%	—	—
Total, Science	4,842,665	5,416,114	4,800,000	-42,665	-0.9%	-616,114	-11.4%

[a/] FY 2011 Enacted Appropriation is prior to the Small Business Innovation Research/Technology Transfer reprogramming and appropriations transfer.

House Mark Language June 2011

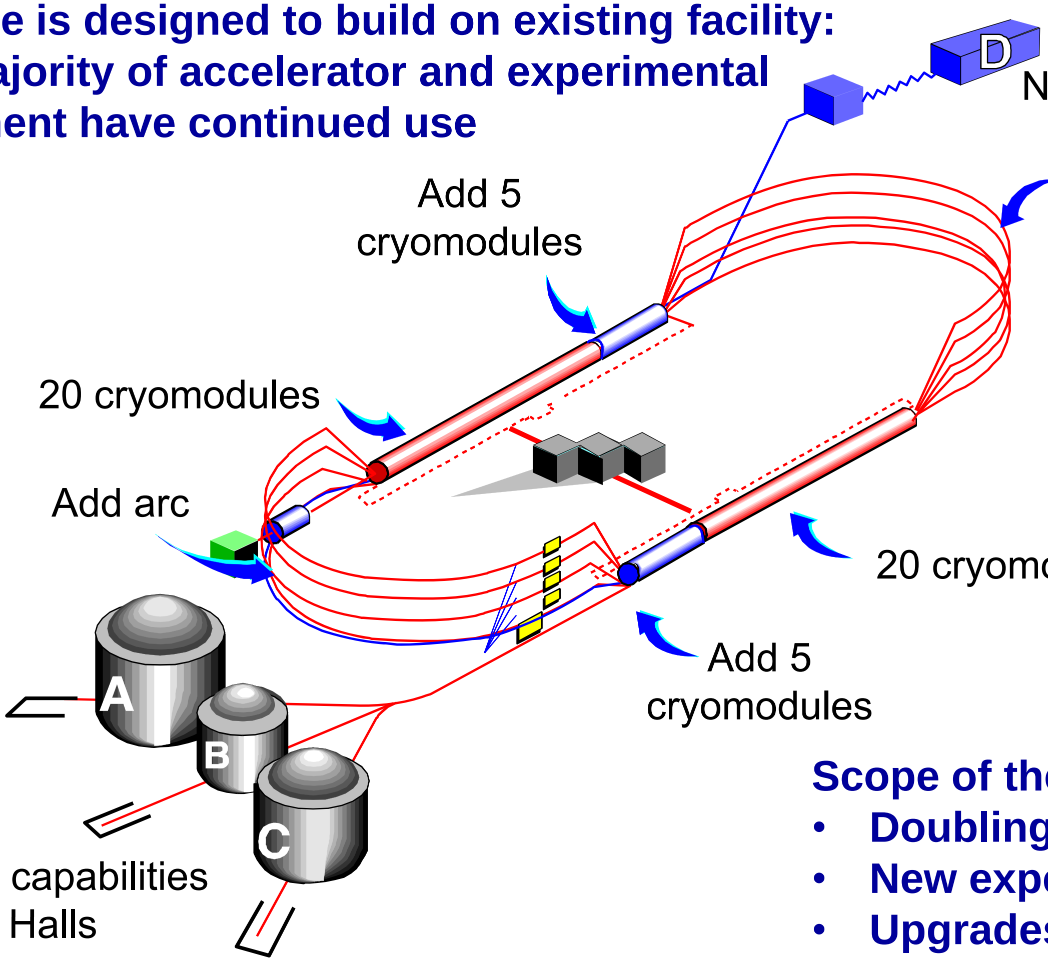


The Committee notes that the Nuclear Physics program has unique experimental capabilities for testing materials under irradiative environments. Materials stressed by intense radiation are important to many technologies, including nuclear fission and nuclear fusion. After the completion of the fusion energy experiment ITER, for example, the most significant technical obstacle to construction of a fully-operational demonstration fusion reactor is the development of containment materials that can withstand a sustained high flux of neutrons without significant degradation. The Committee encourages the Department to consider ways to strengthen productive cooperation between Nuclear Physics and other programs at the Department of Energy to better understand and develop materials that can withstand high levels of radiation.

12 GeV CEBAF Upgrade Project

The energy of CEBAF is being upgraded to 12 GeV
and a new experimental hall is being built

Upgrade is designed to build on existing facility: vast majority of accelerator and experimental equipment have continued use



New Hall

Add 5 cryomodules

Upgrade arc magnets and supplies

20 cryomodules

Add arc

20 cryomodules

Add 5 cryomodules

Enhanced capabilities in existing Halls

Maintain capability to deliver lower pass beam energies: 2.2, 4.4, 6.6….

Scope of the project includes:

- **Doubling the accelerator beam energy**
- **New experimental Hall and beamline**
- **Upgrades to existing Experimental Halls**

Baselined	PYs	FY09 ARRA	FY10	FY11	**FY12**	FY13	FY14	FY15	Total
TPC $M	60	65	20	36	**66**	43	18	2	310

12 GeV CEBAF Upgrade Project: On Schedule, On Budget

With the planned completion of the 12 GeV CEBAF Upgrade in FY 2015, researchers will address

- The search for exotic mesons—a quark and an anti-quark held together by gluons, but unlike conventional mesons, the gluons are excited.
- Physics beyond the Standard Model via high precision studies of parity violation.
- The spin and flavor dependence of valence parton distributions—the heart of the proton, where its quantum numbers are determined.
- The structure of atomic nuclei, exploring how the valence quark structure is modified in a dense nuclear medium.
- Nuclear tomography to discover and explore the three-dimensional structure of the nucleon.

Pouring the foundation for the Hall D complex.

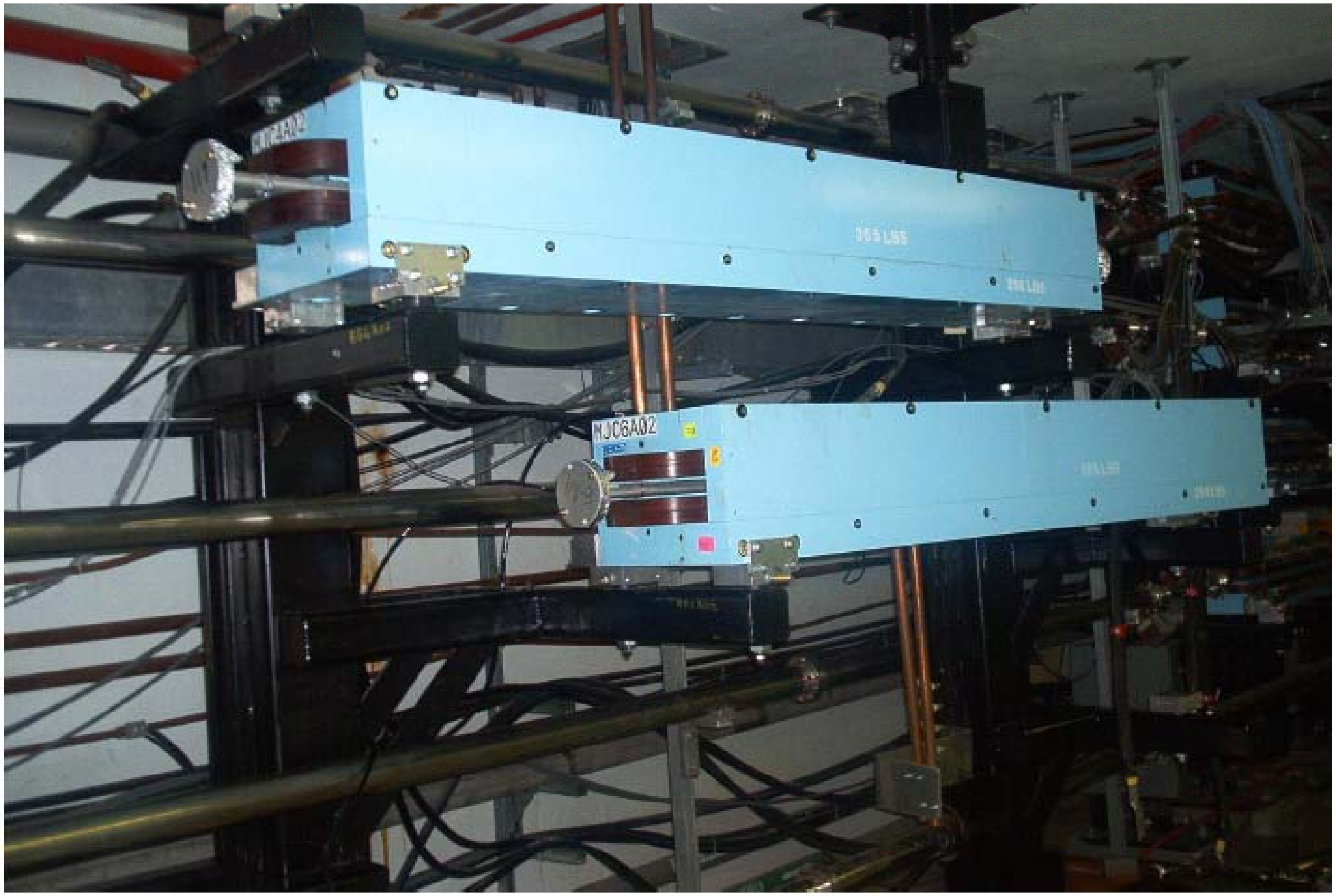
FY 2012 Activities

- Start installation for existing Halls
- Accelerator installation shutdown for 6 months from May-November 2011, and for 12 months from May 2012-May 2013
- Complete accelerator tunnel extension

First completed 12 GeV cavity string being moved into the cryomodule assembly area

New Experimental Hall D - December 2010

First Two Installed 12 GeV Magnets

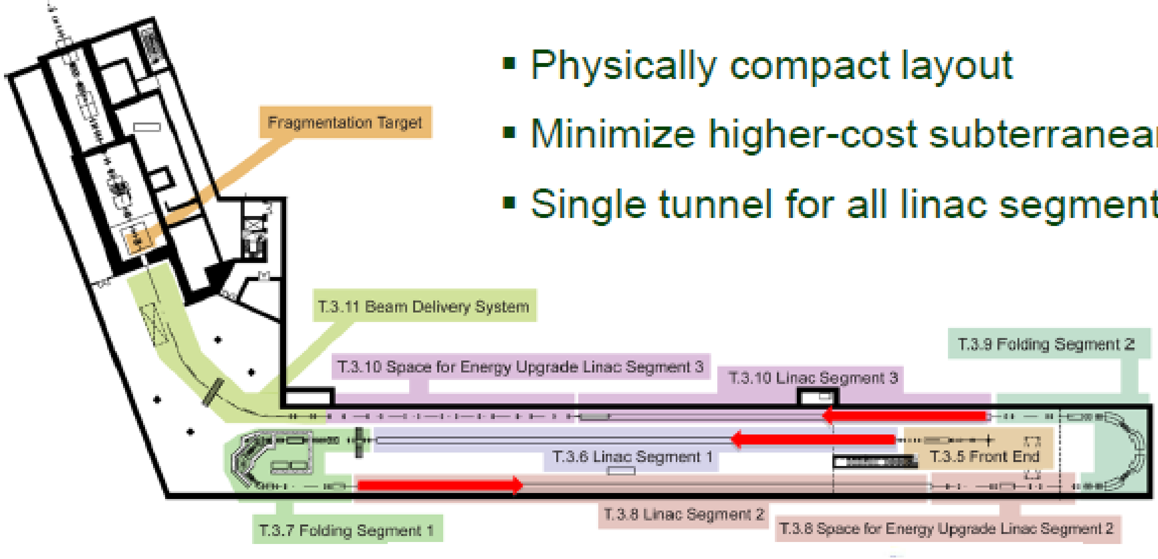


Facility for Rare Isotope Beams at MSU

A New “Microscope” to Study the Structure of Nuclei

Existing NSCL Laboratory

- Critical Decision-1, September 2010
- Steady progress towards Critical Decision-2 (performance baseline)
- DOE Total Project Cost range is $500M-$550M (not including $94.5M from MSU)
- Executed under a Cooperative Agreement with Michigan State University



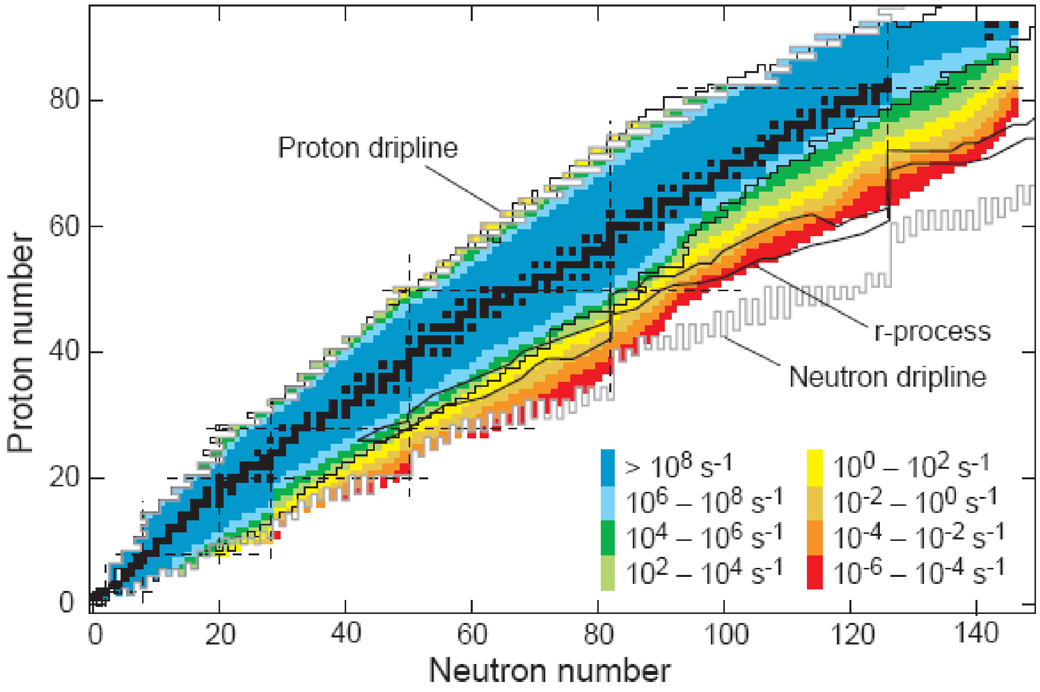
- Physically compact layout
- Minimize higher-cost subterranean structures
- Single tunnel for all linac segments

DOE TPC	$M
FY09	7
FY10	12
FY11	10
FY12	**30**
Outyears	441-491
Total Range	500-550

Facility for Rare Isotope Beams

Science Drivers for FRIB

- **Nuclear Structure**
  - Explore the limits of existence and study new phenomena
  - Possibility of a broadly applicable model of nuclei and how they interact
  - Probing neutron skins
  - Synthesis of superheavy elements
- **Nuclear Astrophysics**
  - The origin of the heavy elements
  - Explosive nucleosynthesis
  - Composition of neutron star crusts
- **Fundamental Symmetries**
  - Tests of fundamental symmetries, Atomic EDMs, Weak Charge
- **Other Scientific Applications**
  - Stockpile stewardship, materials, medical, reactors



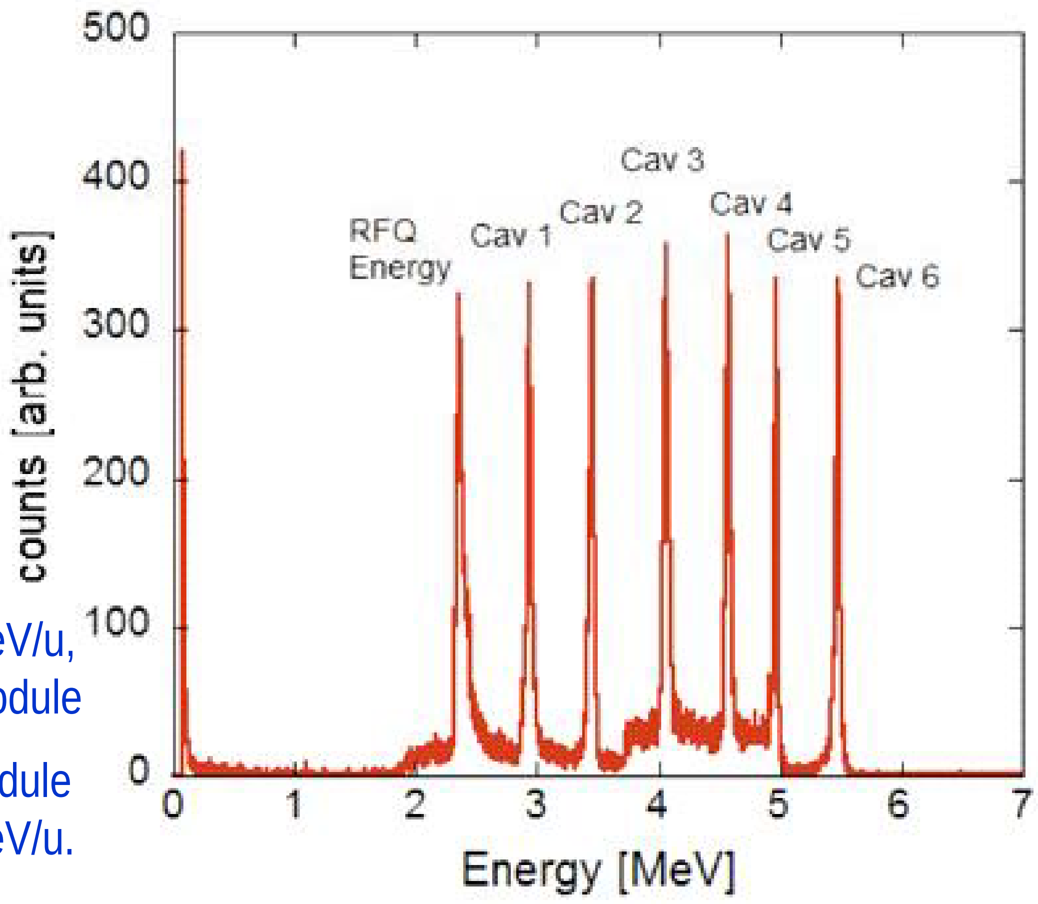
FY 2012 Activities

- Continue engineering and design efforts
- Initiate long-lead procurements
- Possibly pursue a phased-construction start to reduce project risks

First Beam Accelerated to Full Energy Through the Beta=0.041 ReA Cryomodules at MSU

ReA

- A superconducting linac designed to accelerate rare isotope beams from NSCL's Coupled Cyclotron Facility.
- Will provide a wide variety of exotic isotopes at variable energies.
- When FRIB is completed, ReA will be part of the new facility and serve as its post accelerator.



A He^+ beam accelerated by RFQ to 0.6 MeV/u, then rebunched using the first SRF cryomodule

Further accelerated by the second cryomodule to just above the design energy of 1.38 MeV/u.

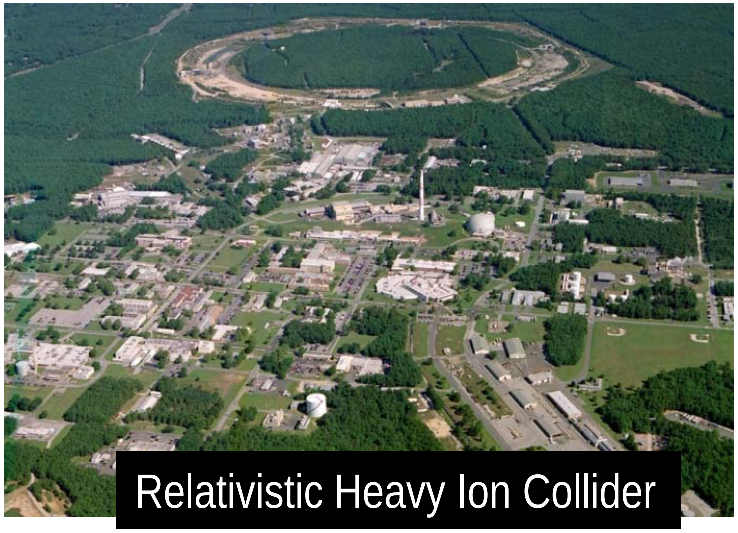
All six cavities operated continuously for 2 weeks with phase and amplitude locked.

Energy spectrum of the accelerated beam using only the RFQ together with the spectrum obtained when one cavity after the other in a 6 cavity cryomodule was turned on and phased for acceleration.

National Science Foundation
WHERE DISCOVERIES BEGIN

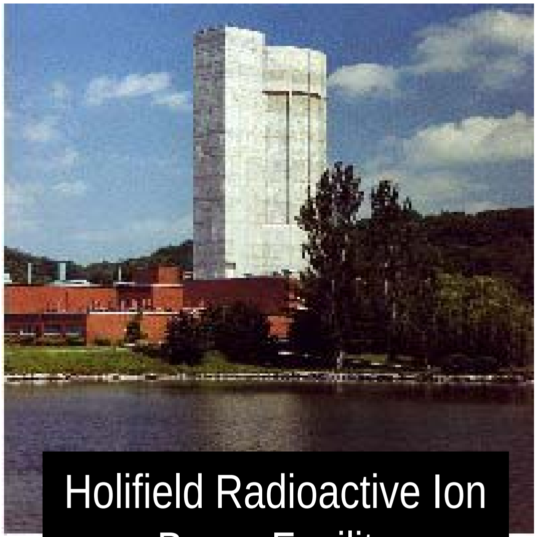
At Present NP Operates Four National User Facilities

“Microscopes” capable of groundbreaking research

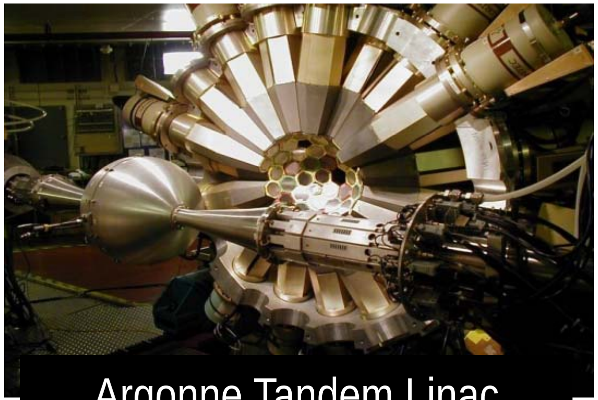


Relativistic Heavy Ion Collider

Continuous Electron Beam Accelerator Facility



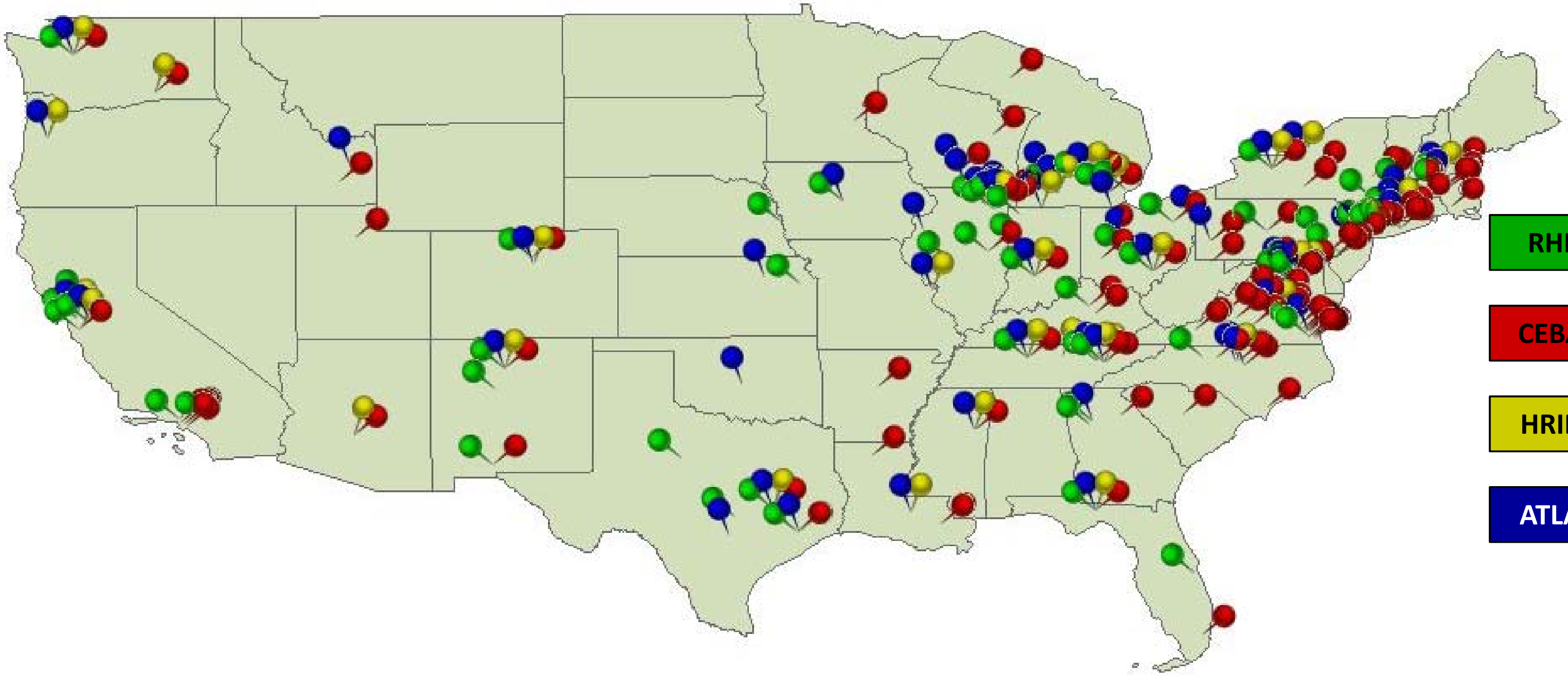
Holifield Radioactive Ion Beam Facility



Argonne Tandem Linac Accelerator System

U.S. Institutions Conducting Research at Nuclear Physics National User Facilities

Approximately 1,900 U.S. users from 32 states and the District of Columbia



- RHIC
- CEBAF
- HRIBF
- ATLAS

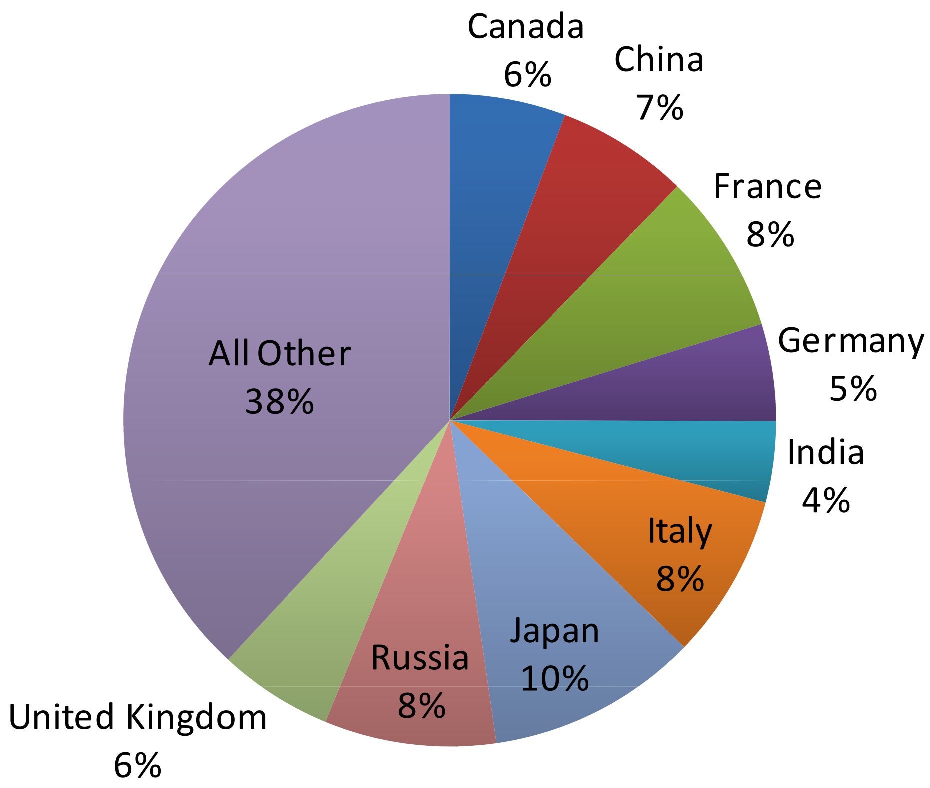
NP supports a scientific workforce of approximately 2,900 FTE's to carry out operations and research at the National User Facilities and related programs

HRIBF is closed as a national user facility in FY 2012, and users will be transitioned to other parts of the program where possible. When FRIB comes on line, the Nuclear Physics program will gain the current NCSL/FRIB user community.

Foreign Participation at Nuclear Physics User Facilities

Approximately 1,300 foreign users from 50 countries conduct research at NP User Facilities

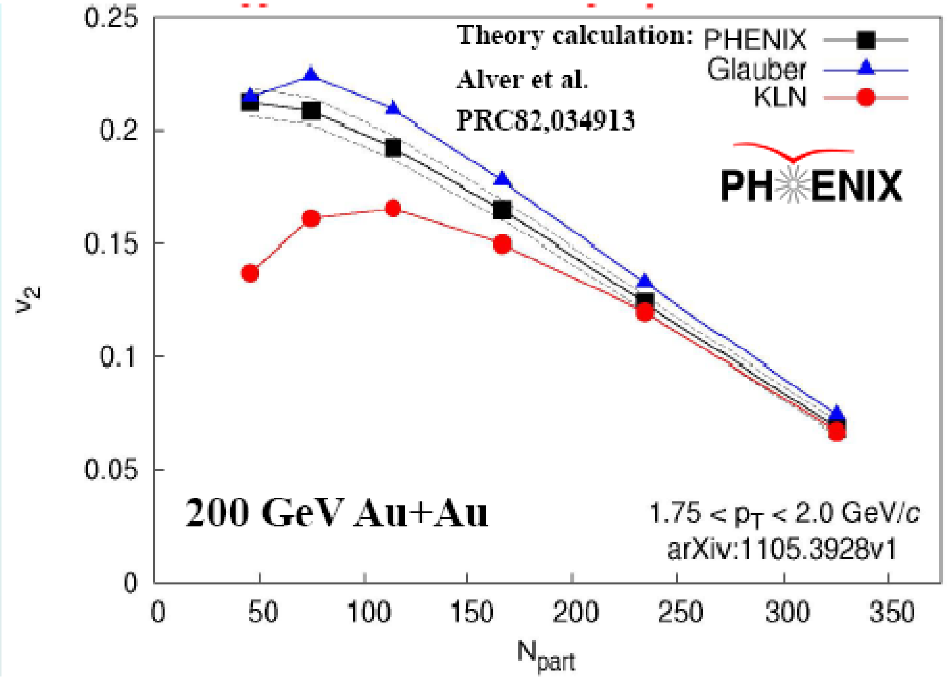
Percentage of Users by Country

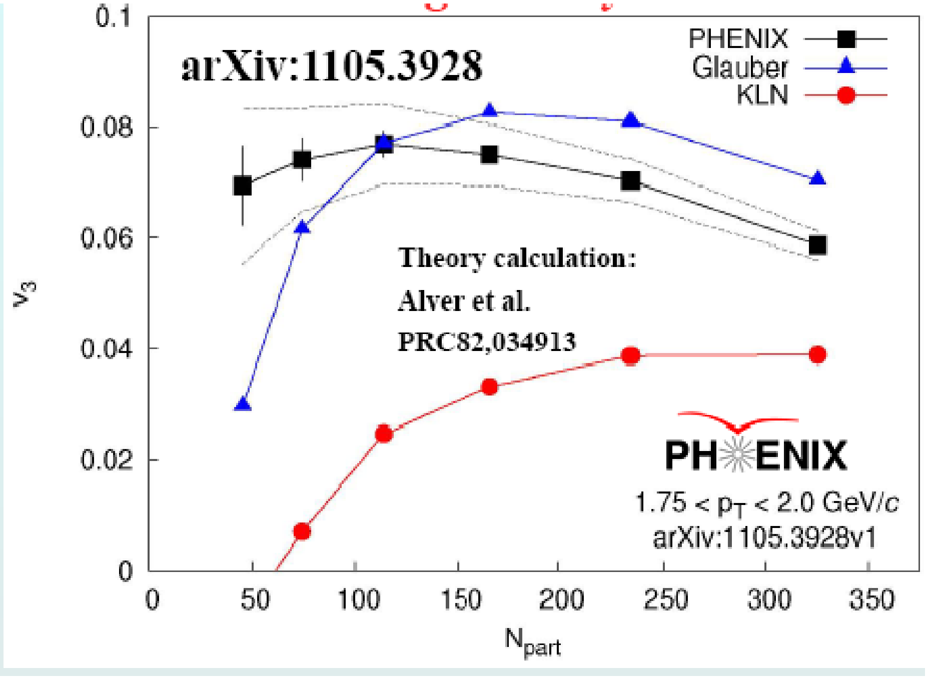


Foreign Participation at U.S. NP National User Facilities provides excellent value:

- U.S. investment at Foreign facilities (e.g. the LHC) is very modest but provides full access to scientific data.
- Foreign participation at U.S. facilities provides very significant capital contributions
- It provides a continuous flow of new ideas and technology.
- It provides very significant contributed effort.

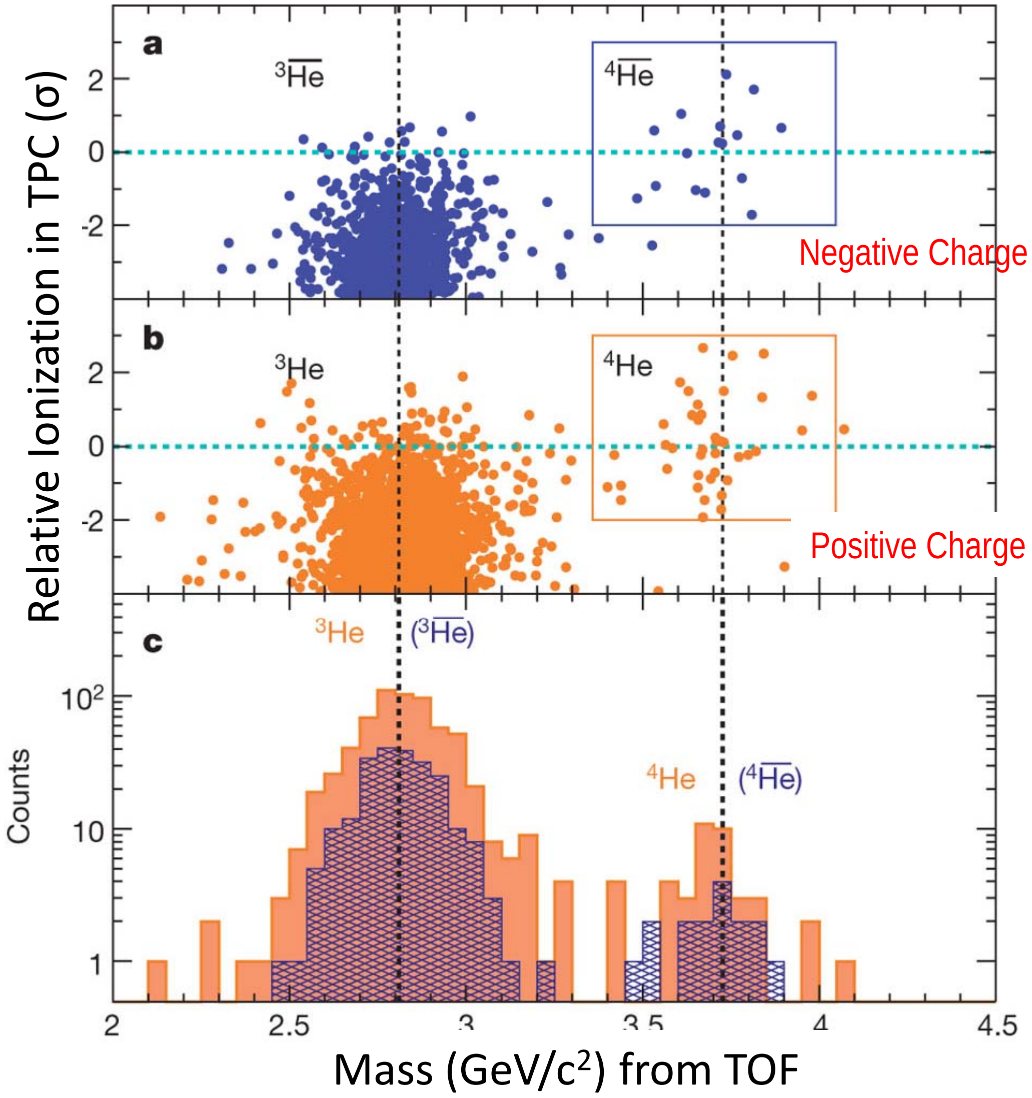
Measurement of Higher Harmonics of Collective Flow ⇒ Path to Quantify How Perfect is the 'Perfect Fluid'





- *Elliptic flow v_2 is sensitive to centrality (impact parameter), shear viscosity/entropy density (η/s), initial-state geometry + fluctuations*
- *Red and blue theory curves use different models of initial-state matter densities and fluctuations, can ~fit v_2 with η/s values differing by factor ~2*
- *Odd flow harmonics would vanish if nuclear overlap were perfectly left-right symmetric, but v_3 arises (primarily) from geometry fluctuations*
- *For given η/s, different models yield quite different v_3 vs. v_2 ⇒ new data will better constrain η/s vis-à-vis String Theory quantum limit $\eta/s \geq ¼\pi$*
- *Still higher v_n should be more sensitive to viscosity damping ⇒ constrain η/s even further by measuring v_n for various colliding species and energies*

US – CAS Collaboration on the Discovery at RHIC of the Heaviest Antimatter Nucleus



This discovery results directly from US – China collaboration (NNSFC, CAS, MOST) on construction of MRPC Time of Flight detector for RHIC/STAR with major contributions from CAS Institutes:

SINAP, USTC, IMP/Lanzhou


LETTER

doi:10.1038/nature10079

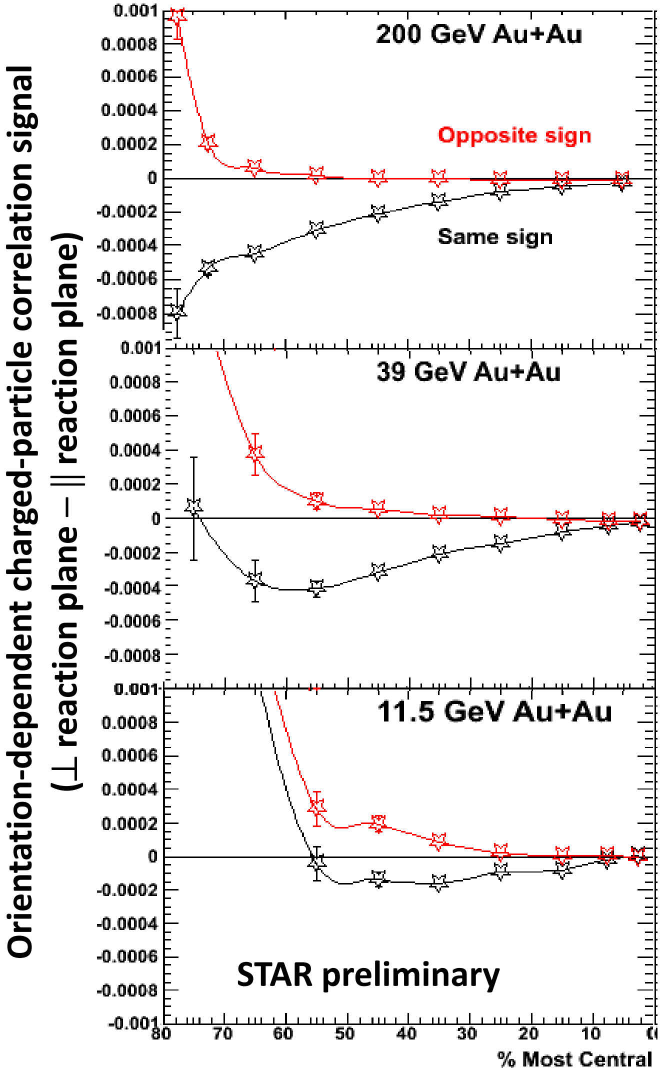
Observation of the antimatter helium-4 nucleus

The STAR Collaboration*

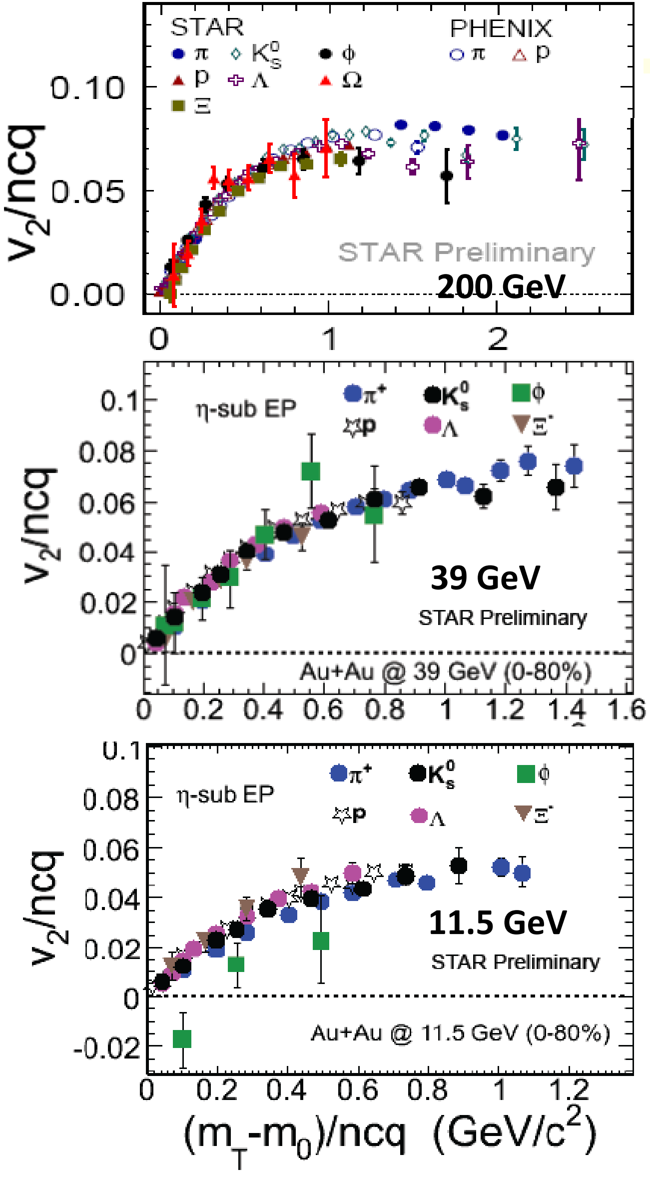
Nature Letters:
Received 14 March;
Accepted 4 April 2011.
Published online 24 April 2011.

New RHIC Data ⇒ Behavior Changes Below $\sqrt{s_{NN}}$ = 39 GeV ⇒ Signal of Onset of Deconfinement?

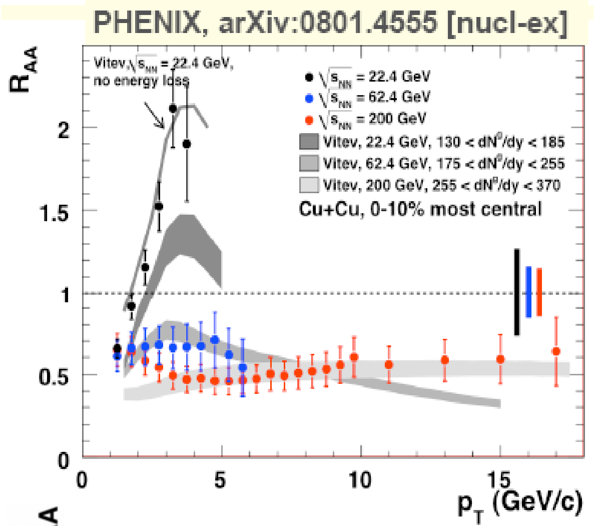
Charge-dependent correl'n con-sistent with Local Parity Violation tends to vanish below 39 GeV

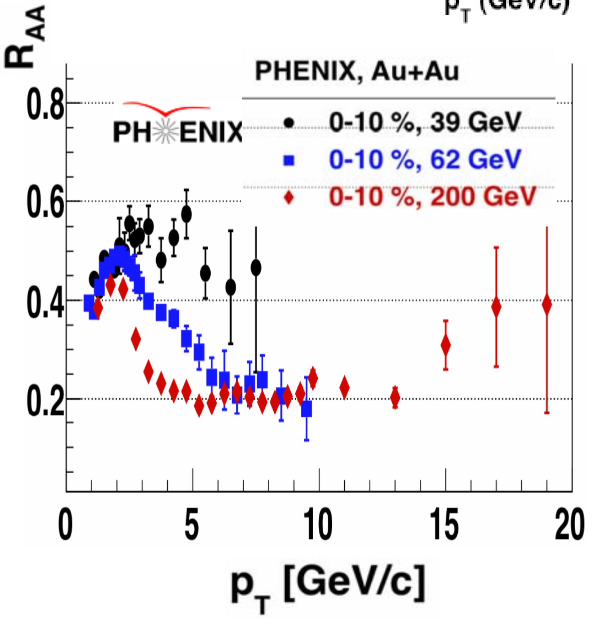


Constituent-quark scaling of elliptic flow less apparent < 39 GeV



High-p_T hadron suppression → enhancement < 39 GeV

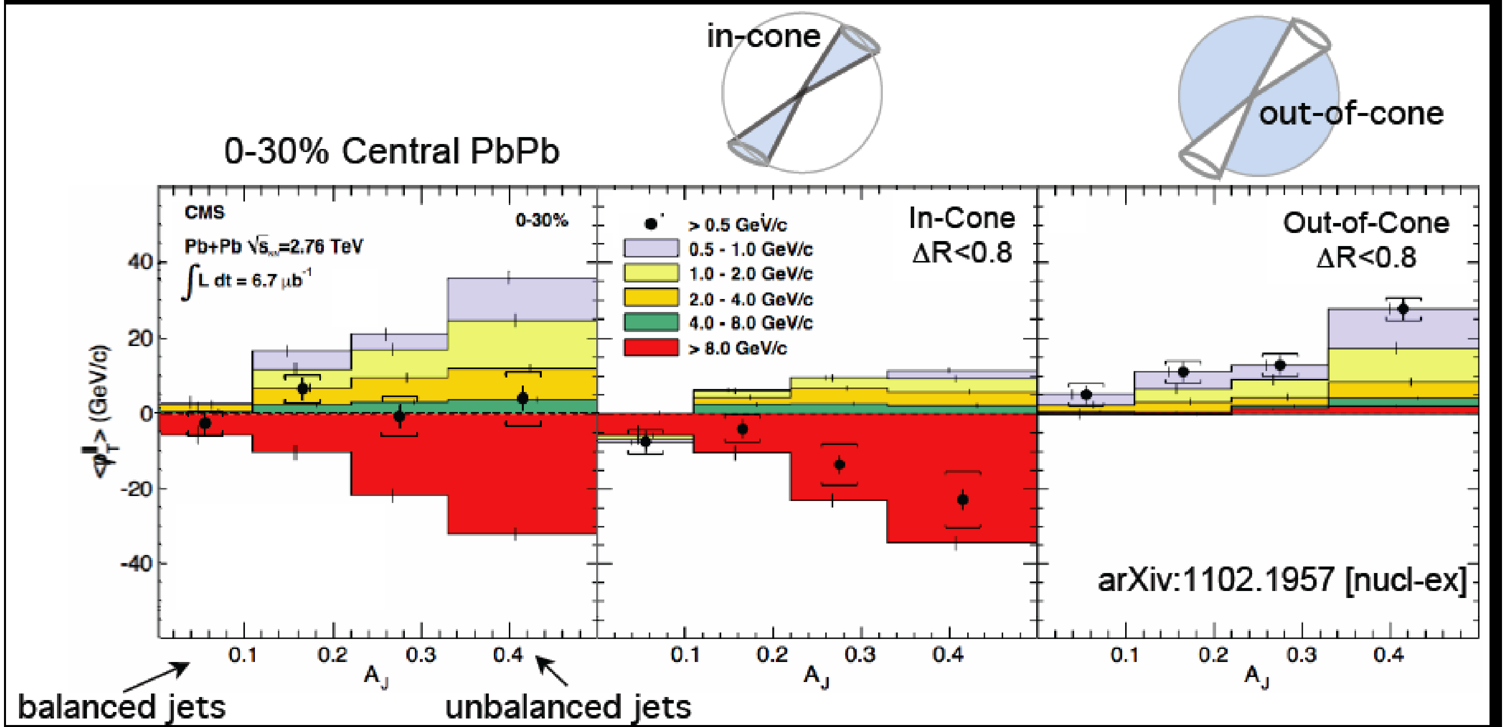


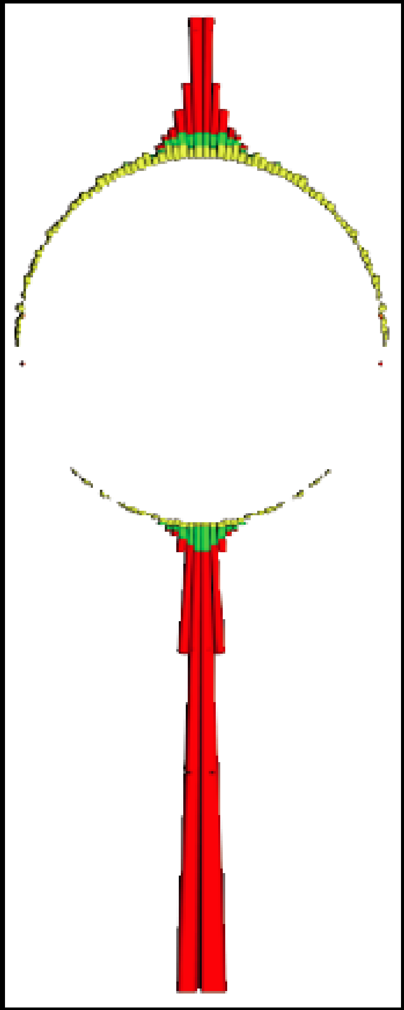


Di-Jets at the LHC – CMS

CMS: arXiv:1102.1957

CMS, C. Roland QM 2011





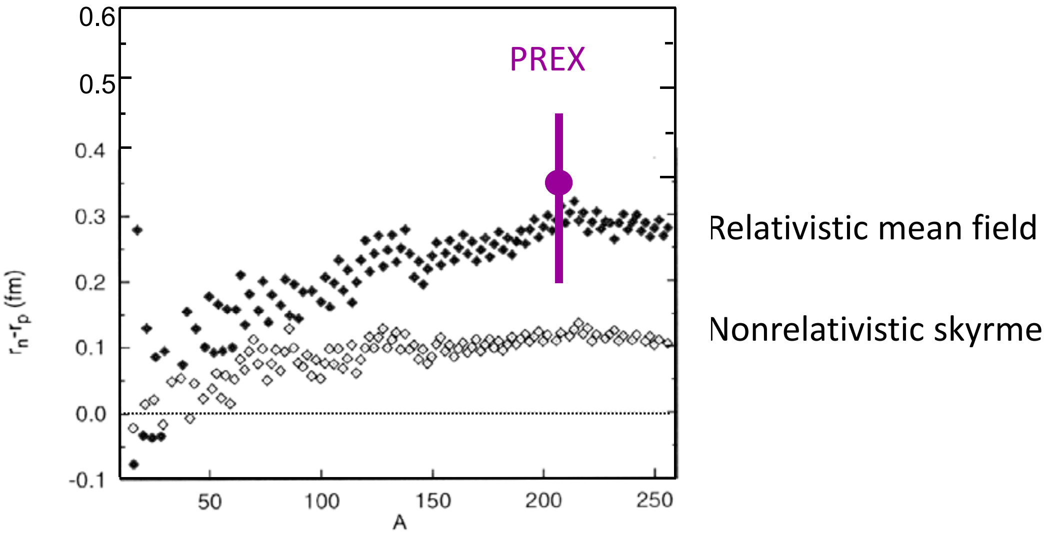
Di-jet energy imbalance offset by lower momentum particles opposite leading jet and outside away-side jet.

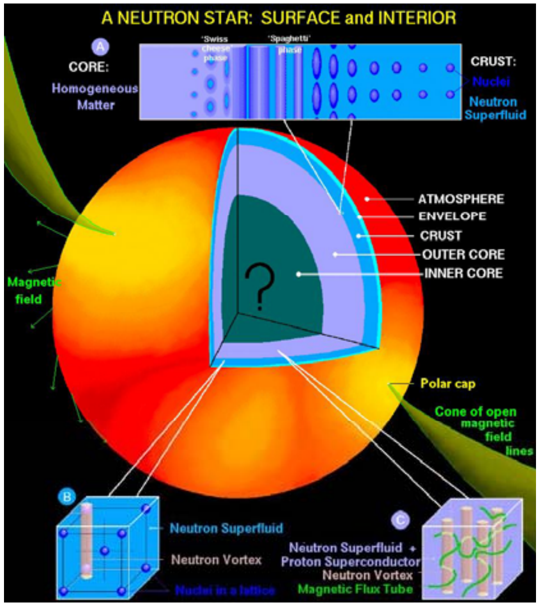
Lead (^{208}Pb) Radius Experiment : PREX

Elastic Scattering Parity-Violating Asymmetry

Z^0 : Clean Probe Couples Mainly to Neutrons

Applications : Nuclear Physics, Neutron Stars,
Atomic Parity, Heavy Ion Collisions





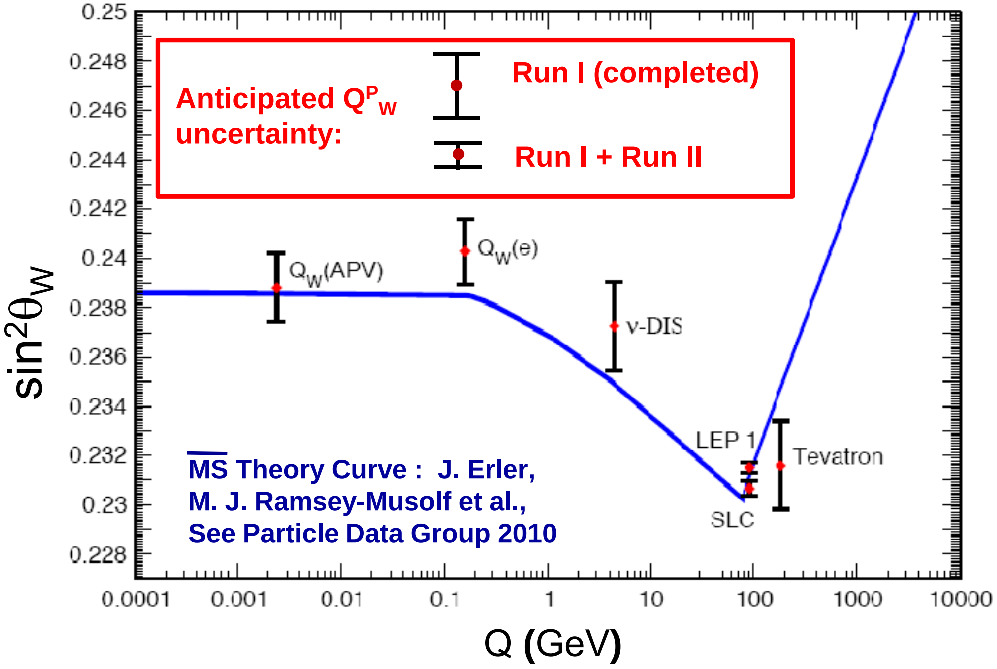
A neutron skin of 0.2 fm or more has implications for our understanding of neutron stars and their ultimate fate

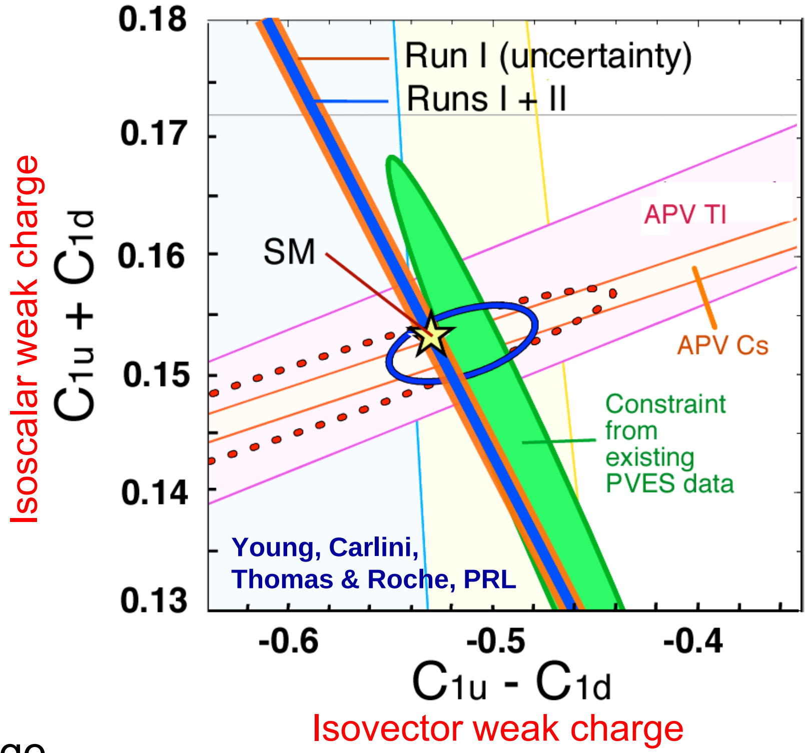
- The Lead (^{208}Pb) Radius Experiment (PREX) finds neutron radius larger than proton radius by +0.35 fm (+0.15, -0.17).
- Result provides model-independent confirmation of the **existence of a neutron skin** relevant for neutron star calculations.
- Follow-up experiment planned to reduce uncertainty by factor of 3 and pin down symmetry energy in EOS

The QWEAK Experiment: Measurement of the Proton's Weak Charge

Elastic $\vec{e}p$ Scattering Parity-Violating Asymmetry

$$Q^P_W = -2\,(2C_{1u} + C_{1d})$$

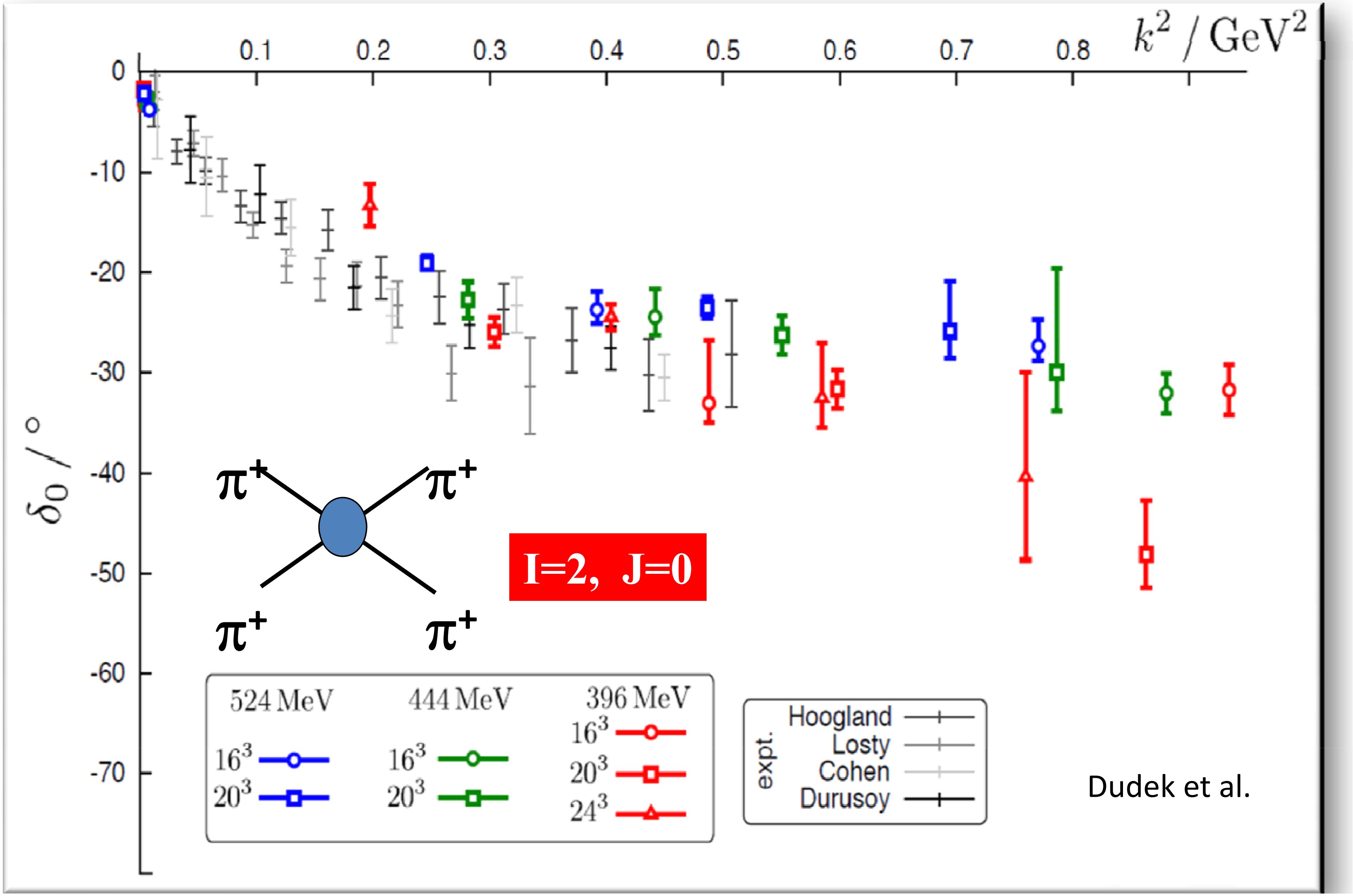




- First direct measurement of the proton's weak charge.
- Precision determination of the neutral current weak couplings to the quarks (C_{1u} & C_{1d}).
- Mass scale reach for parity-violating new physics at expected final uncertainty (95% CL) is ~2.3 TeV.

Anticipated constraints if Q^P_W is consistent with the Standard Model.

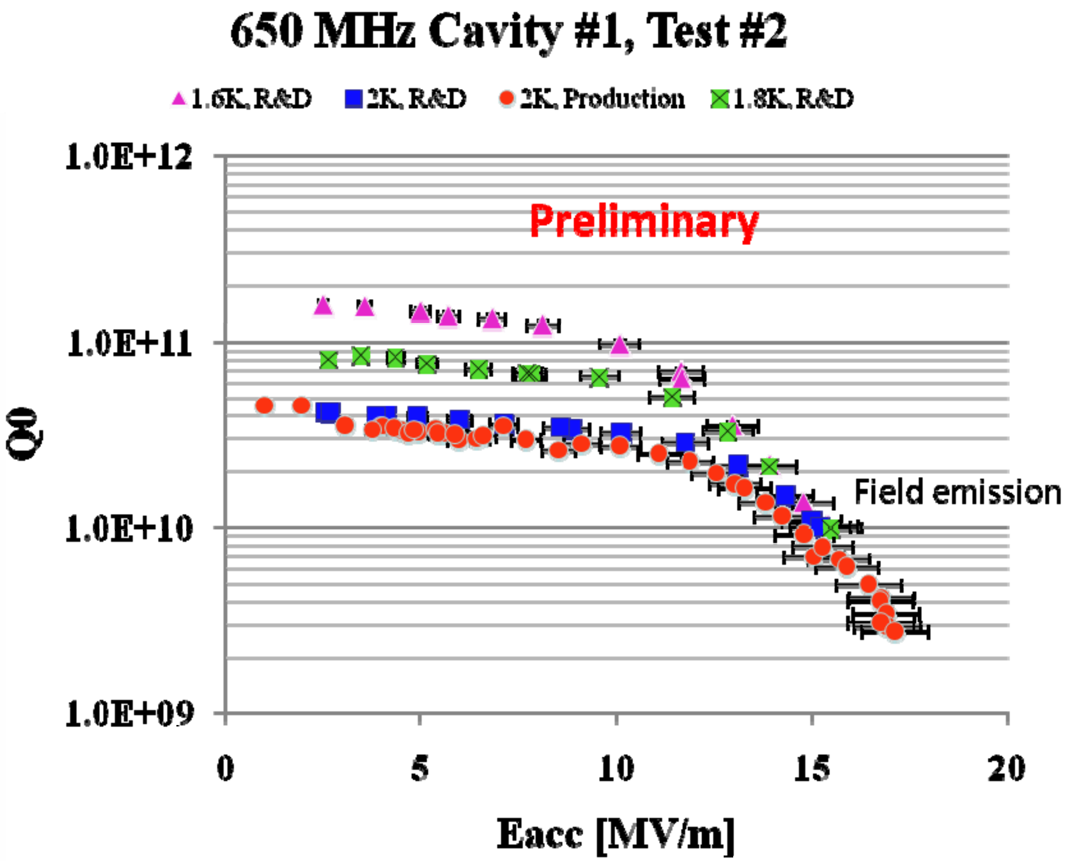
Phase Shifts Calculated on the Lattice



Dudek et al.

650 MHz Cavity for Project X

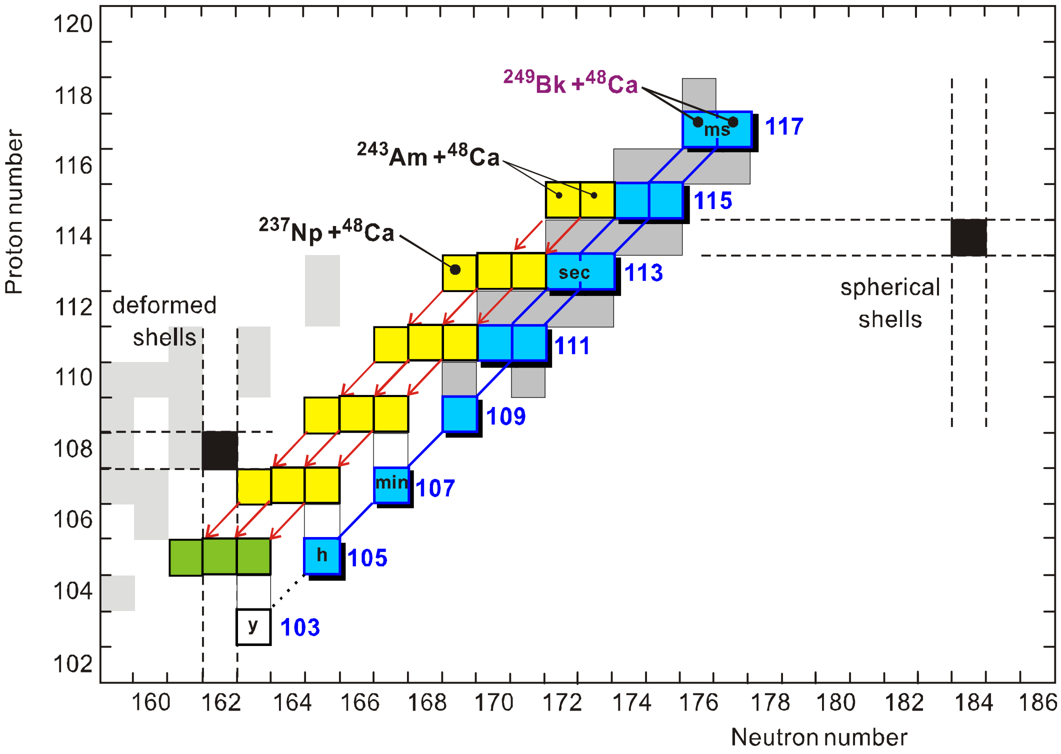
- 650 MHz β=0.61 single cell, designed and fabricated at JLab
- First baseline process cycle using Buffered Chemical Polish
- Field emission limited at higher gradient
- Nice low-field Qo

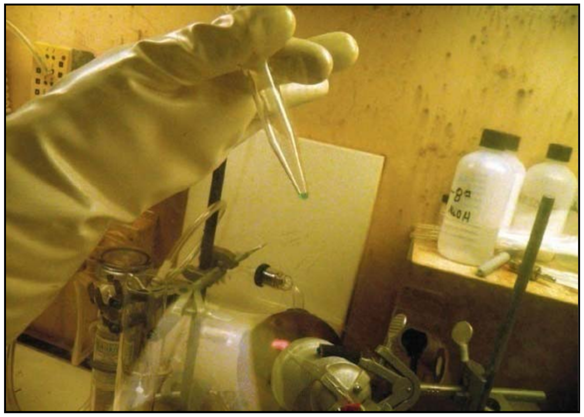


Discovery of Element 117

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?

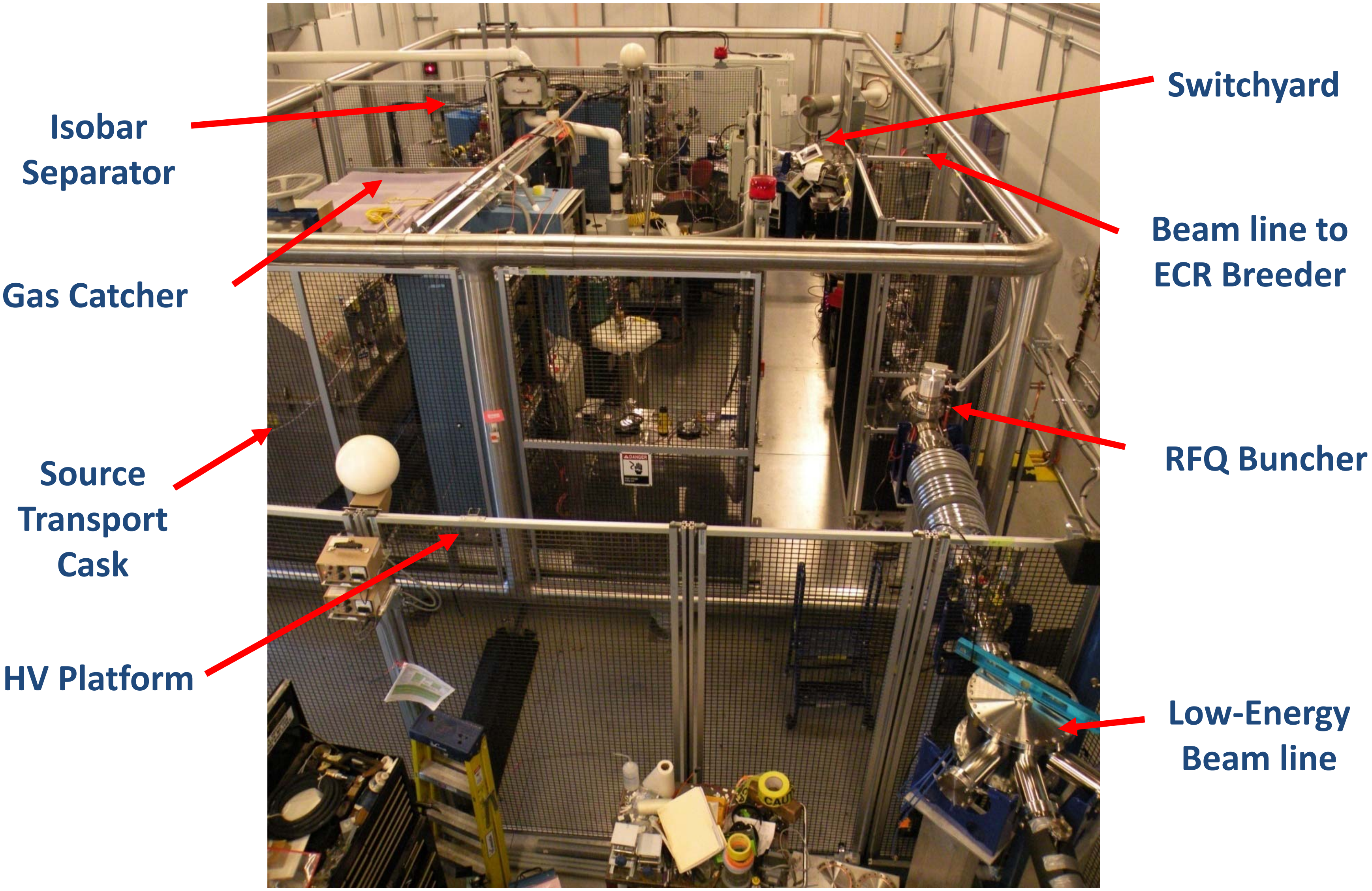




Rare short-lived 248-Bk was produced at HFIR and processed in Isotope Program hot cell facilities at ORNL to purify the 22 mg of target material used for the discovery of element 117.

- 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

CARIBU Commissioning – May 2, 2011



Isobar Separator

Gas Catcher

Source Transport Cask

HV Platform

Switchyard

Beam line to ECR Breeder

RFQ Buncher

Low-Energy Beam line

Installation complete, commissioning complete, development on-going

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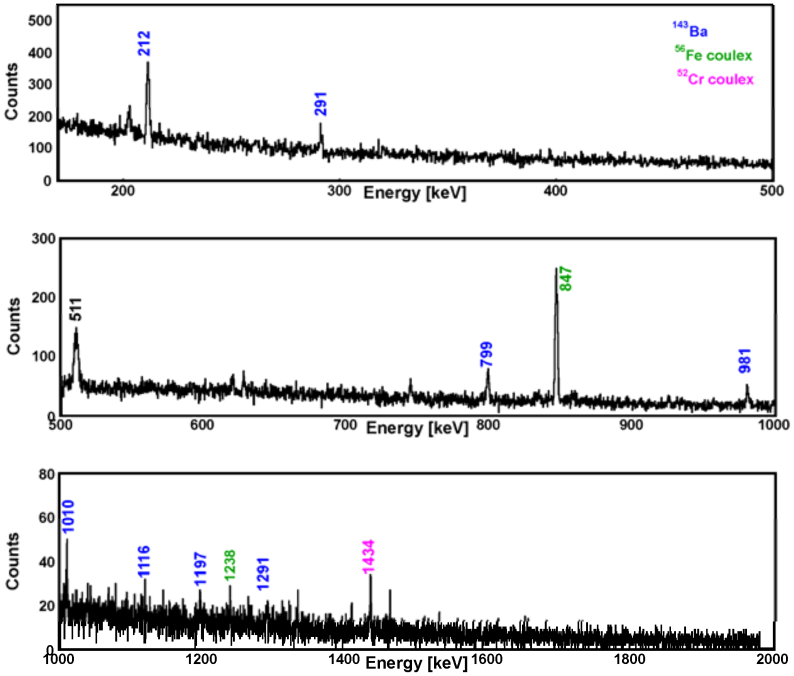
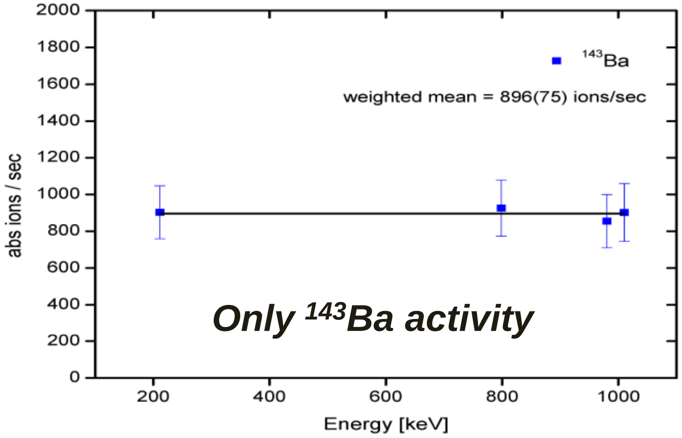
CARIBU Commissioning – May 2, 2011

Spectrum measured after acceleration



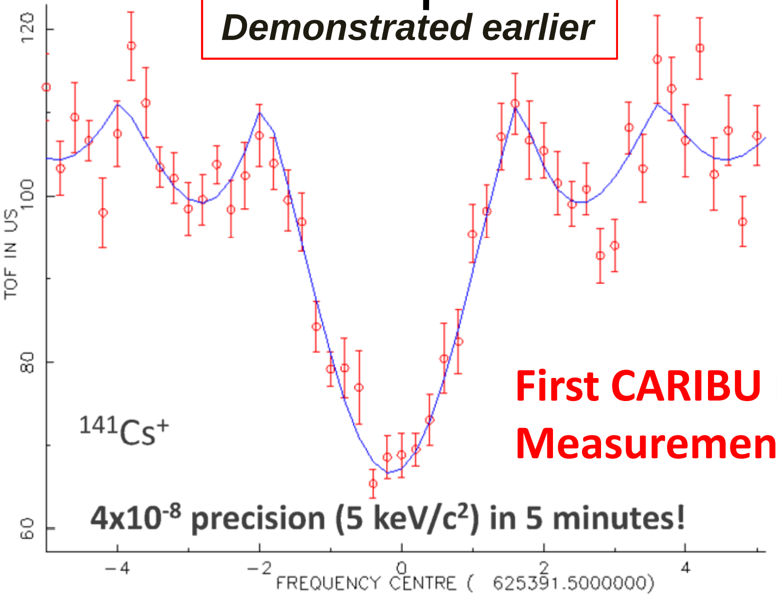


Only ^{143}Ba activity

All requirements met or exceeded

Parameter	Required Value	Achieved on May 2&3, 2011
Beam from Gas Catcher	^{143}Ba^{2+}	^{143}Ba^{2+}
Intensity at Isobar Separator Exit	≥1.2x10^{4} ions/s	>6.0x10^{4} ions/s
Intensity at ATLAS Diagnostics	≥430 ions/s	896±75 ions/s
Charge from Charge Breeder	≥18+	27+
Accelerated Beam Energy	6 MeV/u	6.1 MeV/u
HV Platform Voltage	175 kV	136 kV

Demonstrated earlier

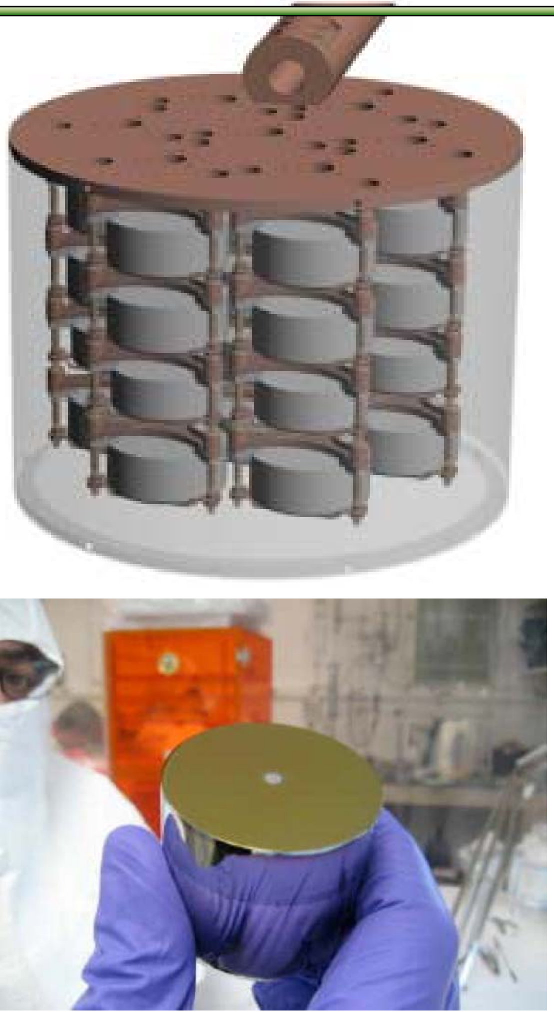


4x10^{-8} precision (5 keV/c^{2}) in 5 minutes!

First CARIBU Mass Measurement at CPT

Present Status of DOE Plans for Underground Science

- DOE remains committed to the science it has planned within its mission:
    - CP violation in the neutrino sector
    - The nature of Dark Matter
    - Search for 0νββ decay.
- It is assessing the impacts and viability of underground science using only DOE resources.
- DOE asked an independent panel to help identify cost-effective options. Final Report was delivered, June 15th, 2011.
- NSF will provide $4M to bridge the funding gap between June and September 2011.
- The Office of Science is requesting $15M in FY 2012 to maintain the viability of the Homestake Mine while assessing its options ($5M of the $15M is requested by Nuclear Physics).



Silicon detector and the cryostat for Majorana Demonstrator, an experiment to determine if the neutrino is its own anti-particle

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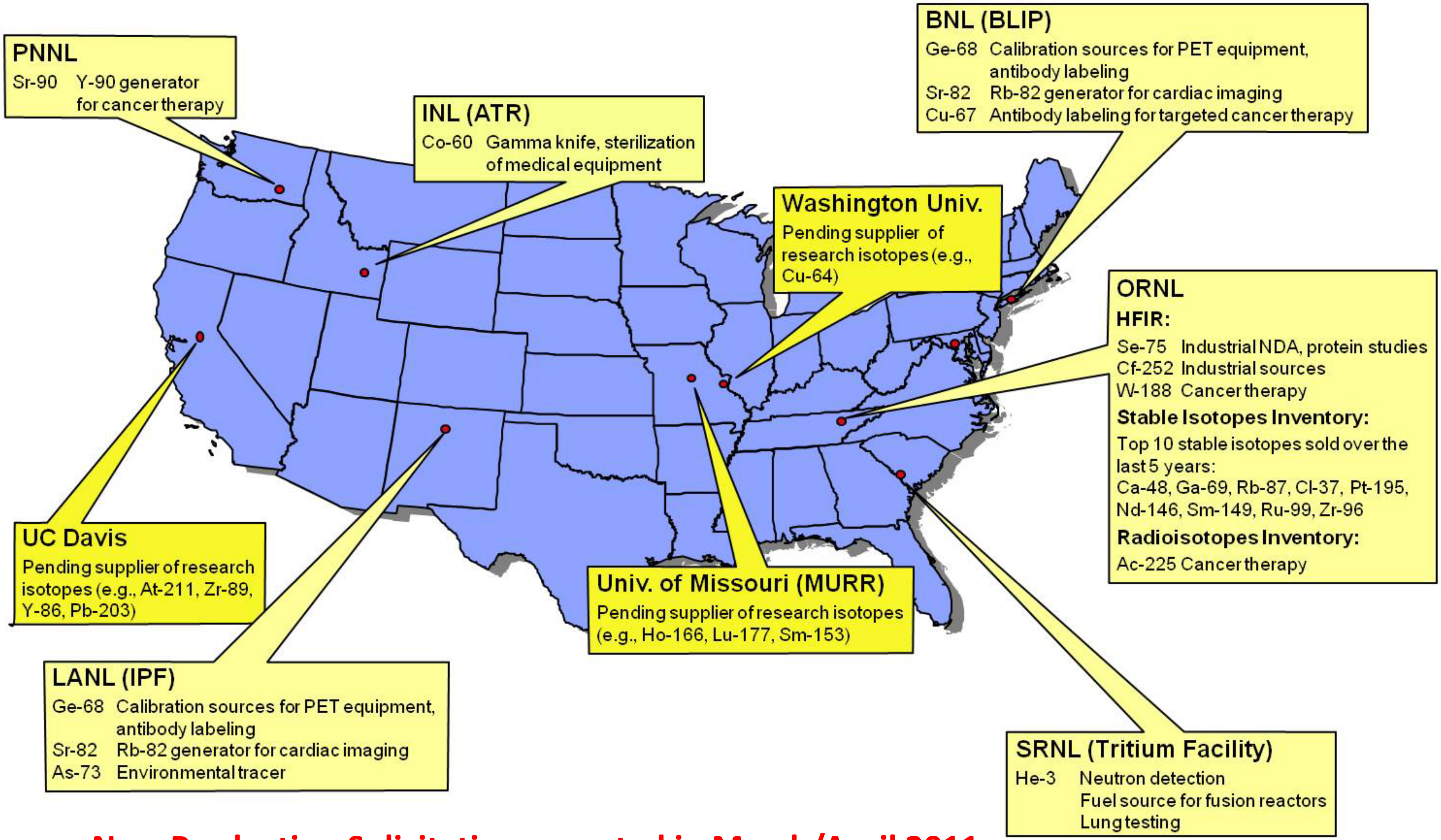
Other Operations: Production Sites Presently Integrated into the Isotope Program



PNNL

Sr-90	Y-90 generator for cancer therapy

INL (ATR)

Co-60	Gamma knife, sterilization of medical equipment

BNL (BLIP)

Ge-68	Calibration sources for PET equipment, antibody labeling
Sr-82	Rb-82 generator for cardiac imaging
Cu-67	Antibody labeling for targeted cancer therapy

Washington Univ.

Pending supplier of research isotopes (e.g., Cu-64)

ORNL

HFIR:

Se-75	Industrial NDA, protein studies
Cf-252	Industrial sources
W-188	Cancer therapy

Stable Isotopes Inventory:

Top 10 stable isotopes sold over the last 5 years:
Ca-48, Ga-69, Rb-87, Cl-37, Pt-195, Nd-146, Sm-149, Ru-99, Zr-96

Radioisotopes Inventory:

Ac-225 Cancer therapy

UC Davis

Pending supplier of research isotopes (e.g., At-211, Zr-89, Y-86, Pb-203)

Univ. of Missouri (MURR)

Pending supplier of research isotopes (e.g., Ho-166, Lu-177, Sm-153)

LANL (IPF)

Ge-68	Calibration sources for PET equipment, antibody labeling
Sr-82	Rb-82 generator for cardiac imaging
As-73	Environmental tracer

SRNL (Tritium Facility)

He-3	Neutron detection Fuel source for fusion reactors Lung testing

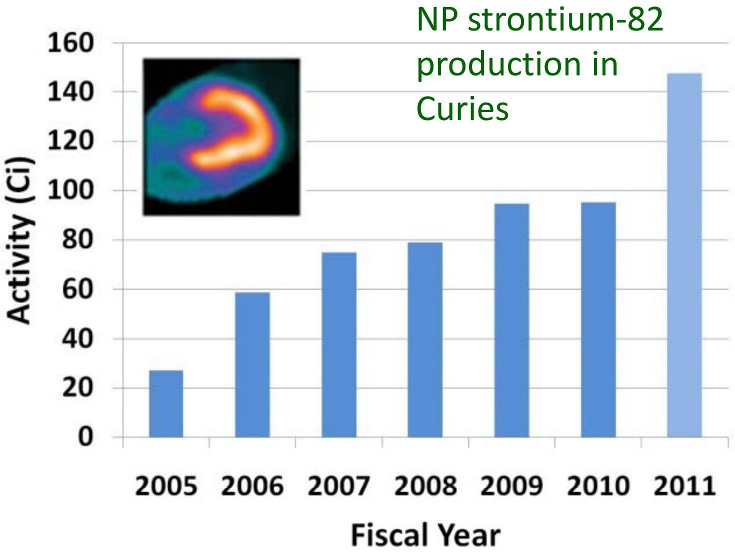
New Production Solicitation expected in March/April 2011

Impacts of NP Facility Operations: 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 exploration 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**

Impacts of NP Research: Radioisotope Production for Research and Commercial Applications

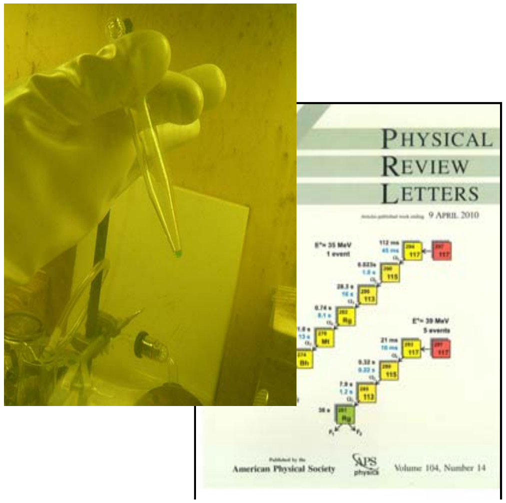
The result of “know-how” from the basic research program

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 20 mg of Bk-249 for a follow-up search to discover element 119 and 120

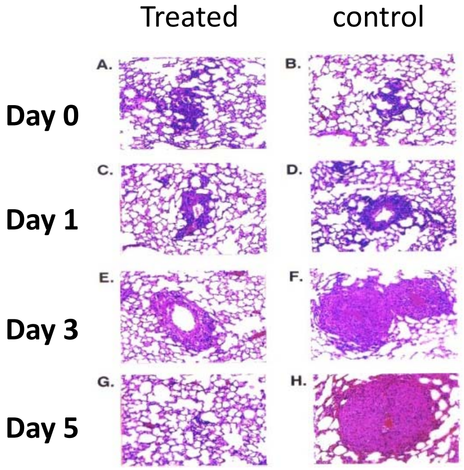
Applied Research Supported

- ~$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



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

Cancer-cell culture experiment: Tumor cells treated with Ac-225 radiopharmaceutical were “cured” while untreated control cells proliferated



A budding Industry Catalyzed by Technology Development 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 started 1995)
Oak Lawn, Illinois

- Anticipate **25% of sales from SRF in 2012**
- SRF sales are presently 25% of the backlog
- 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.

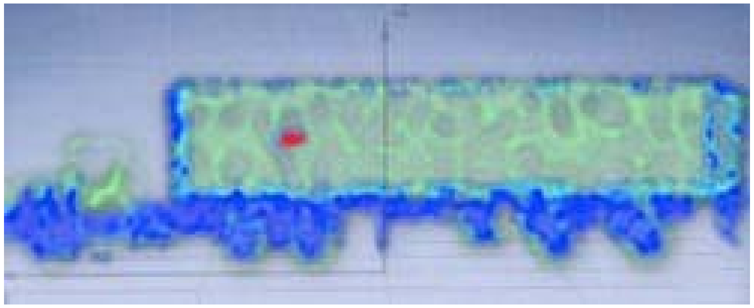
Impacts of competencies developed in NP: Homeland Security, National Defense, and Nuclear Applications Innovation

The result of "know-how" 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.

- Technology transferred to Decision Sciences Corp.
- Large units under construction for installation.
- Potentially a very large market.
- Non-NP program support, but **capability created as a result of NP research.**



A tomographic analysis of a truck showing a "hotspot" of radioactivity. (courtesy Decision Sciences International Corp.)

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.**

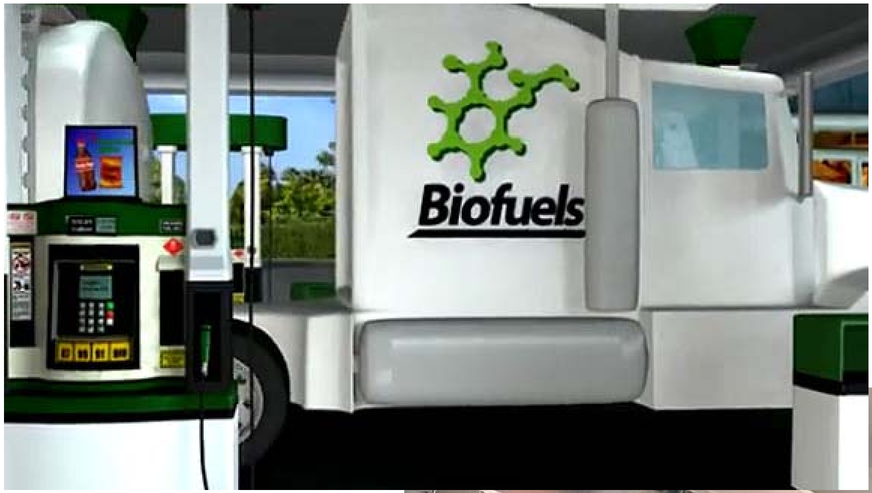
Nuclear Science Know-How and Current Events

Identification of Options for Medium/Long-Term Mitigation Efforts at Fukushima

Technical staff at LANL continue to identify potential technical options for addressing challenges at the site. One example

> Collaborating with the High Energy Accelerator Research Organization (KEK) to develop and approach for using cosmic ray muons to measure the internal position of fuel in the Daiichi reactors. If there is extensive damage to the fuel, the muon technique will identify voids in the fuel structure, or abnormal presence of fuel in lower regions of the reactor pressure vessel. Results will include images of the internal structure of the reactor cores with position resolution in the range 20-30 cm, and should be sufficient to distinguish between volumes of uranium, steel, water, and concrete. These measurements will provide crucial data to decision-makers, to help plan remediation and recovery of the reactor cores. This will be the first time information like has been available for unopened reactors.

A New Look for the Office of Science



http://science.energy.gov/

[Explaining Energy Genomics by DOE Joint Genome Institute]

[Argonne: Discovery on a Mission]

[Firm Uses DOE's Fastest Supercomputer to Streamline Long-Haul Trucks]

Working to get the word out more effectively about the value and importance of SC supported research and technical developments

Department of Energy Office of Science FY2011 Early Career Research Program Office of Nuclear Physics

Dudek, Jozef, Old Dominion University, Norfolk, VA, "Meson Spectroscopy from Quantum Chromodynamics"

Ferracin, Paolo, Lawrence Berkeley National Laboratory, Berkeley, CA, "Development of Nb3Sn Superconducting Magnets for Fourth Generation ECR Ion Sources"

Kneller, James P., North Carolina State University, Raleigh, NC, "The Neutrino: A Better Understanding Through Astrophysics"

Lapi, Suzanne E., Washington University, Saint Louis, MO, "Direct Production of 99MTC Using a Small Medical Cyclotron"

Melconian, Daniel, Texas A&M University, College Station, TX, "Fundamental Electroweak Interaction Studies Using Trapped Atoms and Ions"

Mueller, Peter, Argonne National Laboratory, Argonne, IL, "Weak Interaction Study Using Laser Trapped 6He Atoms"

Quaglioni, Sofia, Lawrence Livermore National Laboratory, Livermore, CA, "Solving the Long-Standing Problem of Low-Energy Nuclear Reactions at the Highest Microscopic Level"

Office of Nuclear Physics

Office of Nuclear Physics

Timothy J. Hallman, Associate Director

Cathy Slaughter, Administrative Specialist

Director's Office Staff

- 11 Technical Advisor (vacant)
- Financial Advisor
  Joanne Wolfe
- Program Analyst
  Cathy Hanlin
- Program Analyst
  Brenda May
- 12 Program Support Assistant
  Vacant

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Christine Izzo, Program Assistant

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  Vacant 11
- Heavy Ion Nuclear Physics
  Gulshan Rai
- Low Energy Nuclear Physics
  Cyrus Baktash
- Fundamental Symmetries
  Vacant 11
- Nuclear Theory
  George Fai
- Nuclear Data and Nuclear Theory Computing
  Ted Barnes
- Nuclear Science Computing
  Vacant 12

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Cassie Dukes, Program Support Specialist
Luisa Romero, Program Analyst

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  Helmut Marsiske
- Advanced Technology R & D
  Manouchehr Farkhondeh
  Lino Micelli- detaillee
- Nuclear Physics Major Initiatives
  James Hawkins
- 12 Applications of Nuclear Science
  Vacant
- Stable Isotopes and Accountable Materials
  11 Vacant
- Isotope Facilities
  Marc Garland
- Isotope R&D
  Dennis Phillips

11 FY 11 Approved

12 On Hold

June 2011

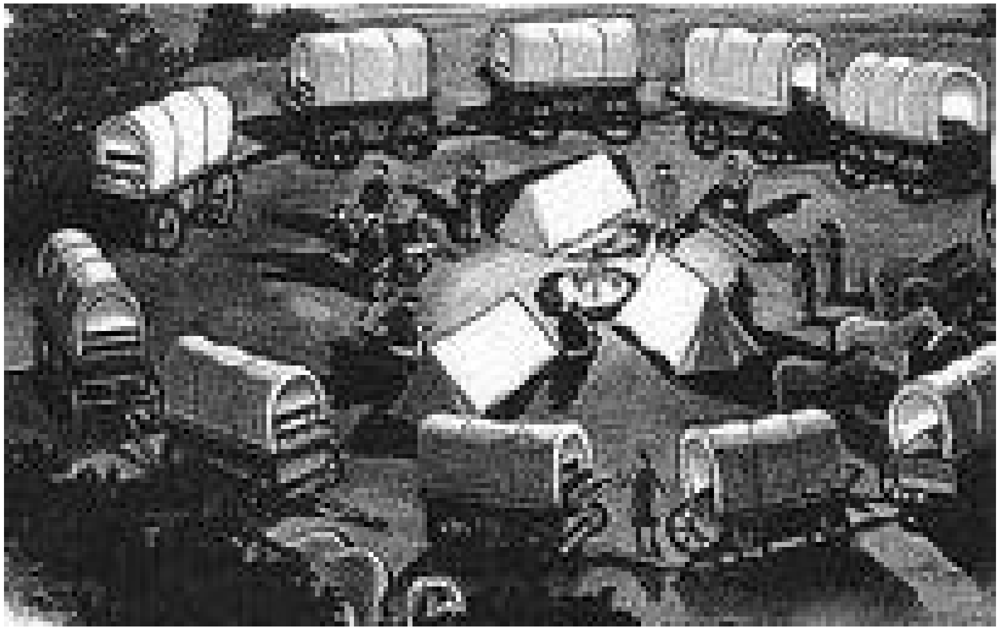
Conclusions

The FY 2012 President's request for Nuclear Physics provides the resources needed:

- To enable U.S. world leadership in discovery science illuminating the properties of nuclear matter in all of its manifestations.
- To provide the tools necessary for scientific and technical advances which will lead to new knowledge, new competencies, and groundbreaking innovation and applications.
- To make strategic investments in facilities and research to provide the U.S. with the premier facilities and tools in the world by the end of the decade for research on:
  - New states of matter 100-1000 times more dense than "normal' nuclear matter at the Relativistic Heavy Ion Collider.
  - The force which binds quarks and gluons in protons and neutrons at the 12 GeV Continuous Electron Beam Accelerator Facility.
  - The limits of nuclear existence for neutron and proton rich nuclei at the Facility for Rare Isotope Beams and the Argonne Tandem Linac Accelerator System.
  - The nature and fundamental properties of neutrinos and neutrons and their role in the matter-antimatter asymmetry of the universe.
  - The development, and production of stable and radioactive isotopes for science, medicine, industry, and national security.

To Support the President's FY2012 Request:

- Keep doing the compelling science that got us here
- Keep demonstrating excellence in every thing we do (science, construction projects, R&D, outreach)
- Keep spreading the word (importance, relevance, value)



A great tide floats all boats