



U.S. DEPARTMENT OF  
**ENERGY**

---

## Office of Nuclear Physics

### SBIR/STTR Information Exchange Meeting

September 13, 2010

Jehanne Gillo

Director, Facilities and Project Management Division



# 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

# SC Nuclear Physics Program is the Federal Steward

## DOE/SC is the largest supporter of nuclear physics in the US and operates large National User Facilities

### Responsible for Strategic Planning and Funding

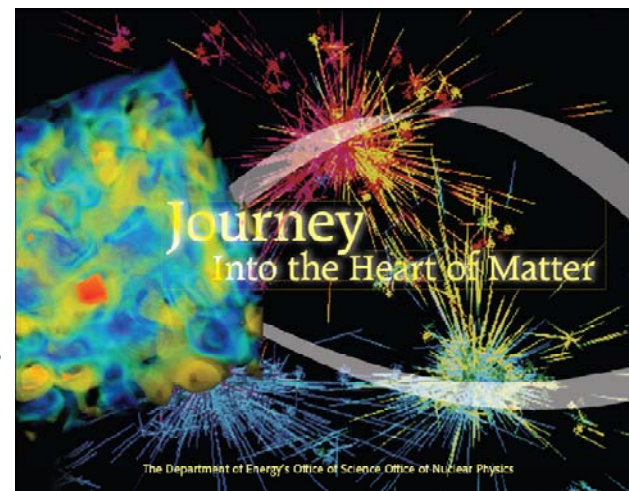
- Identify the scientific opportunities for discoveries and advancements
- Build and operate forefront facilities to address these opportunities
- Develop and support a research community that delivers significant outcomes
- Work with other agencies/countries to optimize use of U.S. resources

### Goals are:

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

### Deliverables are:

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





# Nuclear Physics Program in the U.S.

### National User Facilities

- RHIC (BNL)
- CEBAF (TJNAF)
- ATLAS (ANL)
- HRIBF (ORNL)

### Research Groups

- 9 National Laboratories
- 85 Universities

### NP Workforce

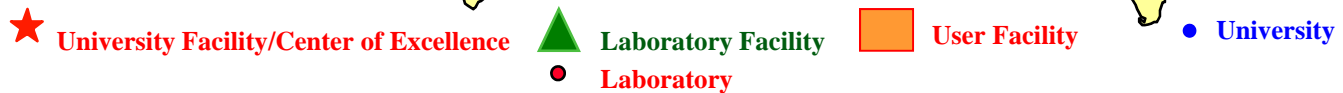
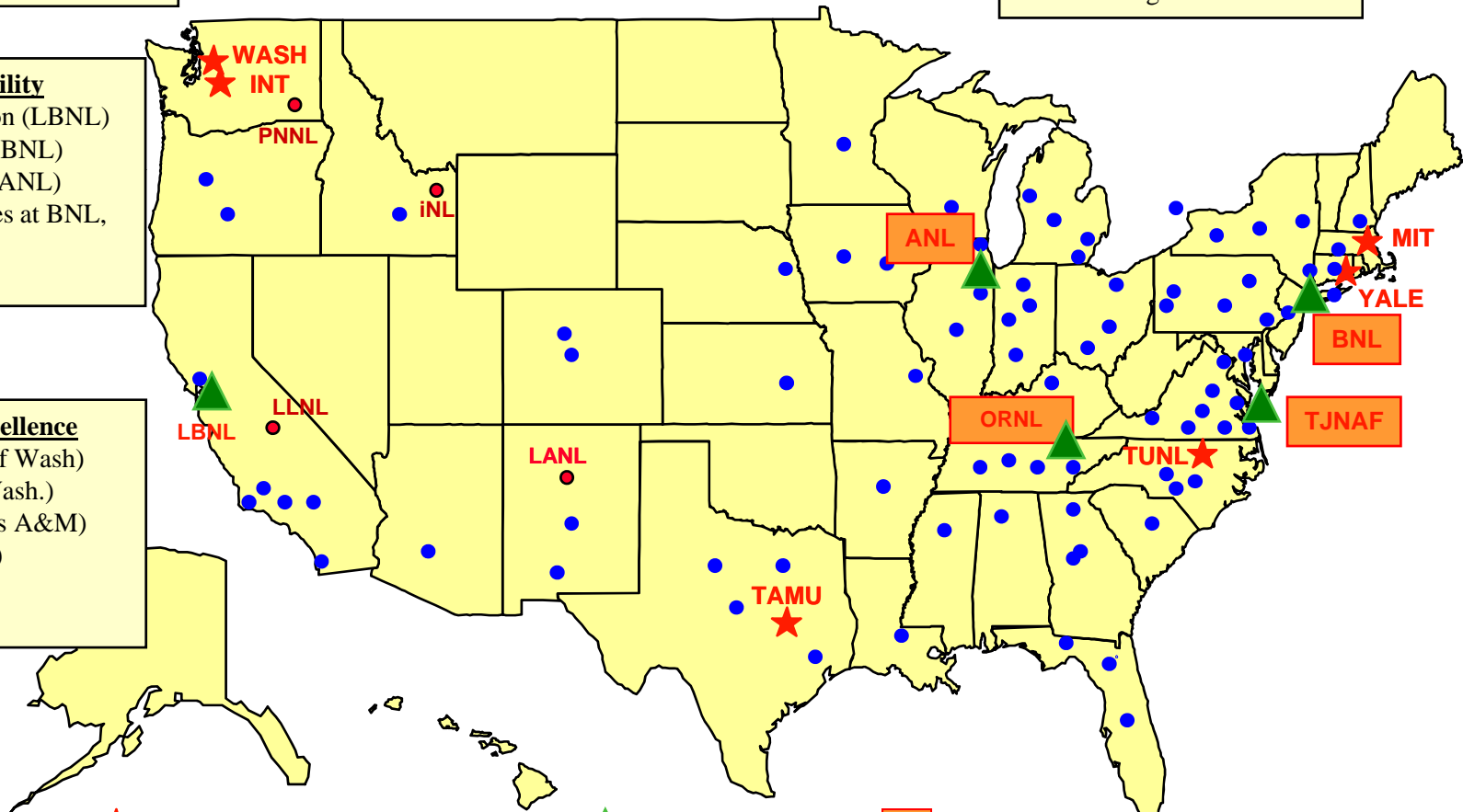
- ~720 Faculty & Lab Res Staff
- ~400 Post-docs
- ~500 Graduate Students
- ~100 Undergraduate Students

### Other Lab. Facility

- 88-Inch Cyclotron (LBNL)
- 200 MeV BLIP (BNL)
- 100 MeV IPF (LANL)
- Hot Cell Facilities at BNL, LANL, ORNL

### Centers of Excellence

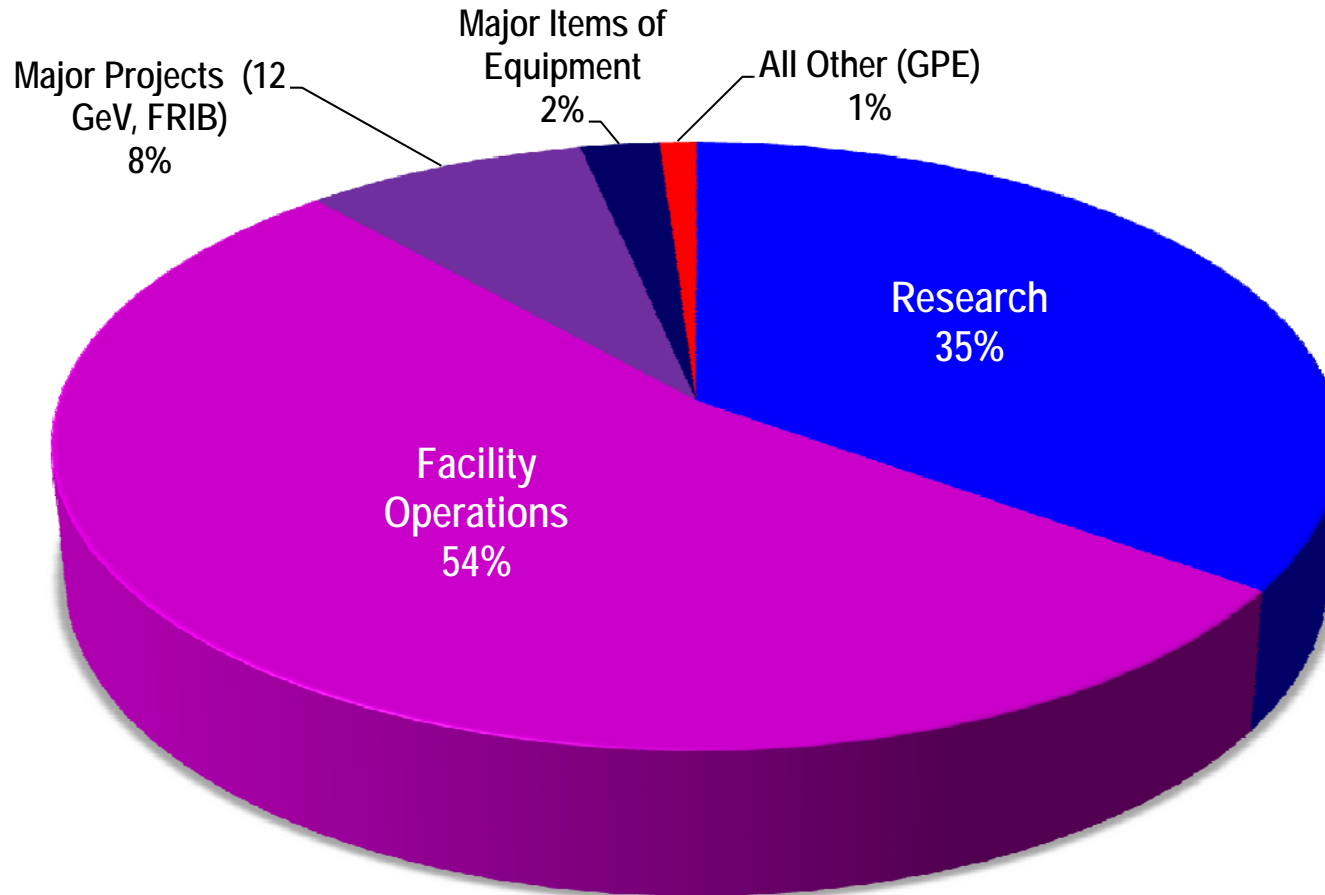
- CENPA (U. of Wash.)
- INT (U. of Wash.)
- TAMU (Texas A&M)
- TUNL (Duke)
- REC (MIT)
- WNSL (Yale)





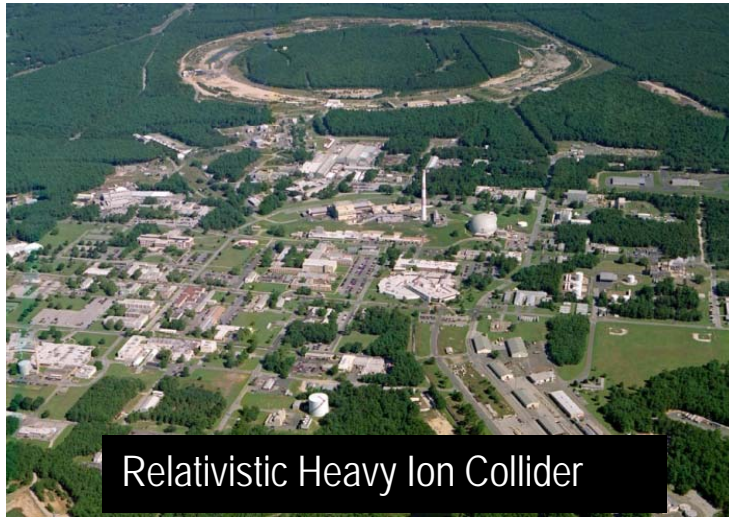
# FY 2011 Congressional Request Nuclear Physics by Major Function

65% of the NP budget supports operations or construction of facilities & instrumentation



*FY 2011 Congressional Request  
Total = \$562.0M*



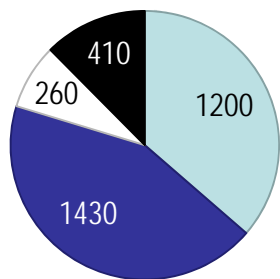


Relativistic Heavy Ion Collider

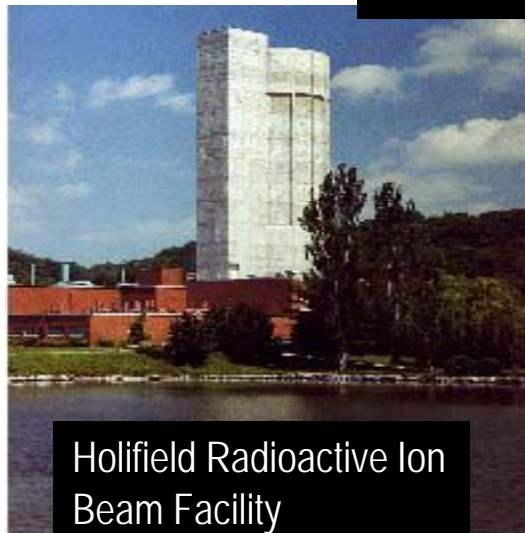


Continuous Electron Beam Accelerator Facility

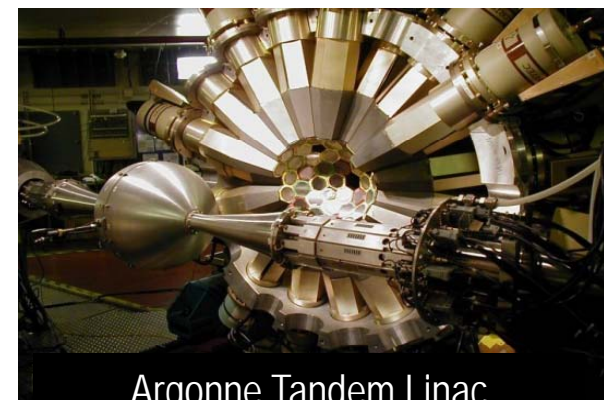
## Users of NP Facilities



- RHIC/BNL
- CEBAF/TJNAF
- HRIBF/ORNL
- ATLAS/ANL



Holifield Radioactive Ion Beam Facility

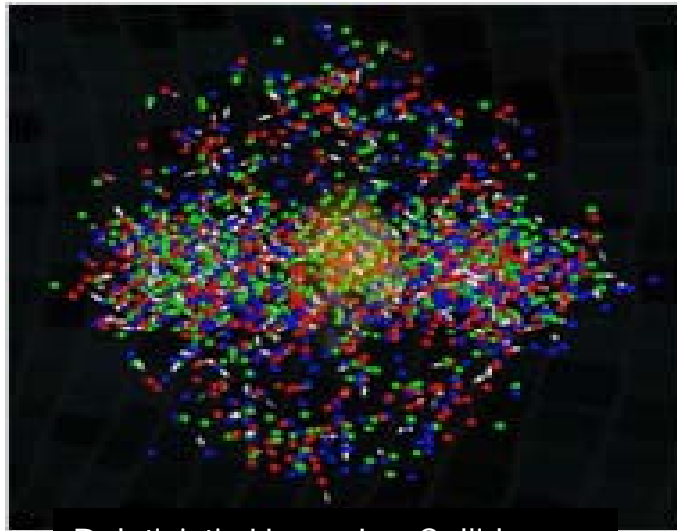


Argonne Tandem Linac Accelerator System



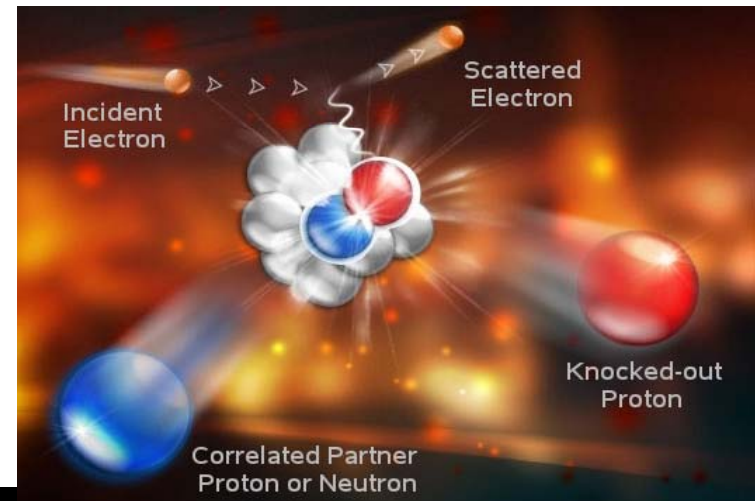
# At the NP National User Facilities the Research Spans a Range of Microscopic Scales:

*From Quarks and Gluons*



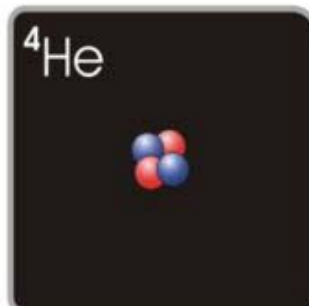
Relativistic Heavy Ion Collider

*To Protons and Neutrons*

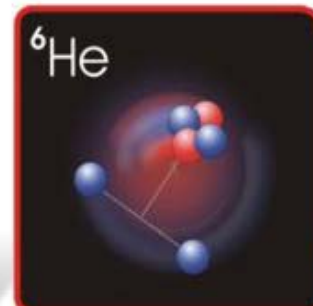


Continuous Electron Beam Accelerator Facility

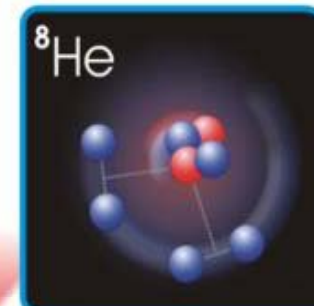
*To Nuclei*



Holifield Radioactive Ion  
Beam Facility



Argonne Tandem Linac  
Accelerator System



## NP has Five Subprograms

---

- **Medium Energy**
  - Primarily explores the the frontier of quantum chromodynamics
  - Spin structure of the proton
  - Parity violating processes relevant to the New Standard Model
- **Heavy Ion**
  - Investigates the frontier of quantum chromodynamics via studies of hot, dense nuclear matter
- **Low Energy**
  - 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



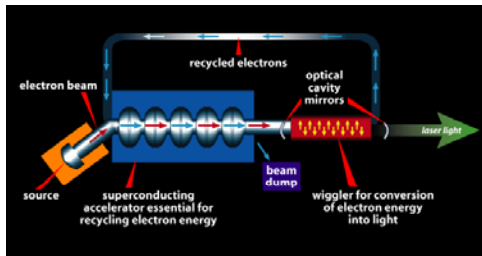


# CEBAF at JLab provides polarized 6 GeV electron beams

## Accelerator Core Competencies



SNS SC RF cavities at JLAB



Developed most powerful FEL



Single crystal Niobium gives promise for high gradients for acceleration (ILC)

## World's Premier Facility for studies of:

- Quark structure of matter
- Nuclear structure and weak interactions with polarized electrons

## Core Competencies utilized by others

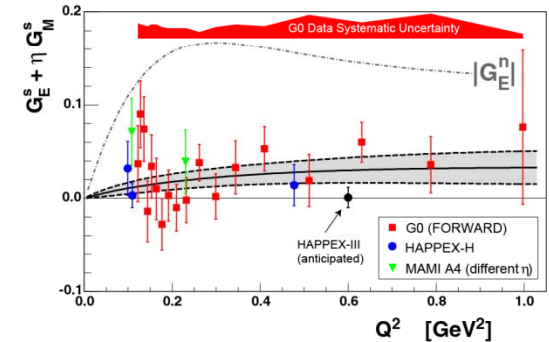
- SRF cavities for SNS
- Improvements in cryogenics (efficiencies)
- FEL and ERL for USN/USAF
- SRF cavities for FRIB
- SRF cavities for ILC R&D
- Technology transfer

## CEBAF Jefferson Laboratory



## Premier NP User Facility

- User community of ~1350
- Outstanding science



- Nucleon weak coupling
- Quark structure of the nucleon
- Quark flavor masses

## Technology Transfer



Dillon Gamma Camera used in scanning for breast cancer



# 12 GeV CEBAF Upgrade Project

## Unique, world-class facility and scientific program

- Doubling the accelerator beam energy
- New experimental Hall and associated beamline
- Upgrades to the existing three experimental Halls

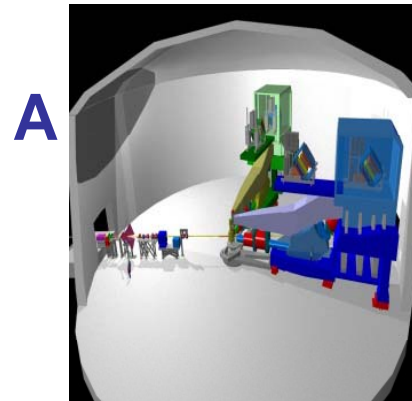
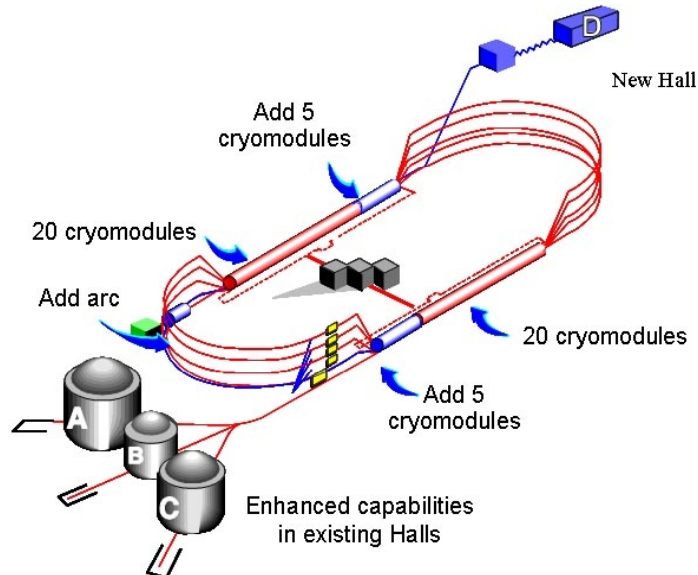
## TPC: \$310 Million

Funds redirected from CEBAF Operations

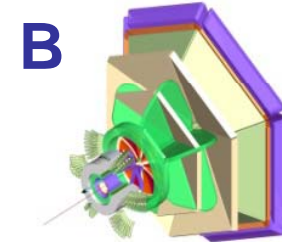
Successful CD-2, CD-3 in FY 2008

Operations anticipated in FY 2015

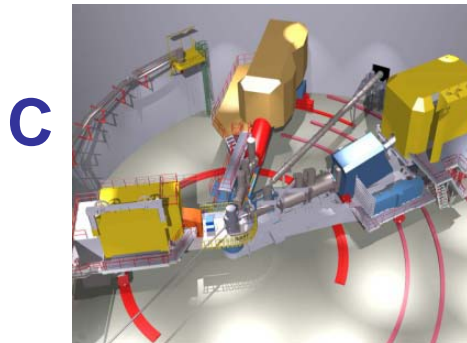
Recovery Act funding advances project funding by \$65 Million and reduces cost and schedule risk



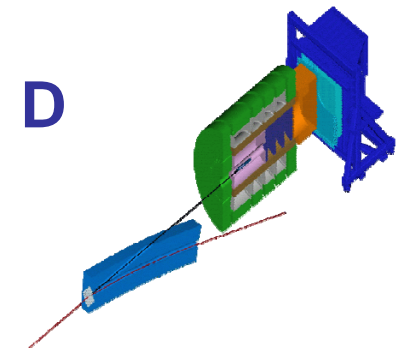
A High Resolution Spectrometer (HRS) Pair, and specialized large installation experiments



B CLAS upgraded to higher ( $10^{35}$ ) luminosity and coverage



C Super High Momentum Spectrometer (SHMS) at high luminosity and forward angles



D 9 GeV tagged polarized photons and a 4π hermetic detector



**U.S. DEPARTMENT OF ENERGY**

# Implementing the Recommendations of the Long Range Plan: Construction of Hall D



*Pouring the foundation for the Hall D complex.*





# RHIC at BNL - Heavy Ion Beams and High Energy Polarized Protons

## Capabilities used by others

BLIP (DOE IPA)



NSRL (NASA)



Tandem van de Graaff (SEU, micro-filter)

## World's Premier Facility for studies of:

- **Hot, dense nuclear matter**
- **Structure of the proton**

## Unique Capabilities utilized by Others

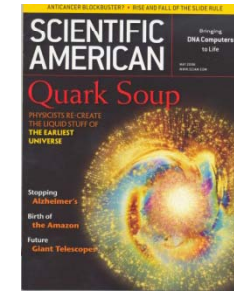
- NASA (NSRL)
- DOE NE (BLIP)
- NASA, others (SEU, commercial)

## Core Competencies utilized by others

- Synchrotron for SNS
- Magnets/Tier I Center for LHC
- USN work for ERL
- Technology transfer

## Premier NP User Facility

- User community of ~1200
- Outstanding Science

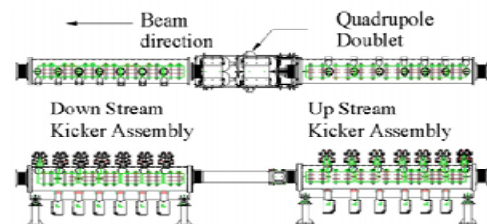


- “Perfect” QGP liquid
- Connection to string theory
- Proton’s spin (gluons)

## Accelerator Core Competencies

- Synchrotron and component for SNS
- Magnets for LHC
- ERL for USN
- Designs for medical synchrotrons

## RHIC Brookhaven National Laboratory



Fast kicker system designed and built for the SNS

## Instrumentation Core Competency

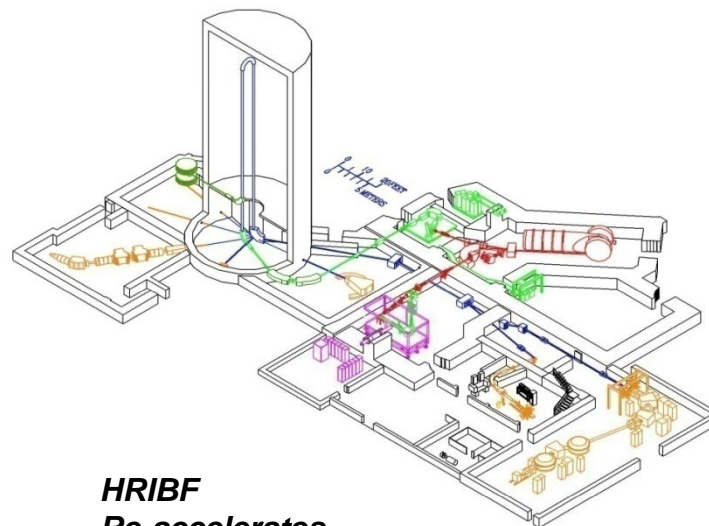
- World-class Instrumentation Group
- Awake Animal Imaging
- Micro-electronics/detectors for PET
- etc.



Awake animal imaging

# ATLAS and HRIBF Provide Stable and Radioactive Beams

- **Capabilities:**
  - ATLAS: stable beams ( $1 < A < 238$ ) with energies  $> 8$  MeV/u
  - HRIBF:  $> 175$  radioactive ion beams with energies above the Coulomb barrier for Sn
- **Programs:**
  - ATLAS: NS at the proton drip line,  $N=Z$  and heavy nuclei; CNO cycle breakout and cosmogenic gamma-ray emitters; precision mass measurements
  - HRIBF: delayed proton decay, NS at the proton drip line, closed-shell neutron rich nuclei; CNO cycle breakout,  $rp$ - and  $r$ -processes
- **New Capabilities:**
  - ATLAS: CARIBU source of complementary RIBs; HELIOS spectrometer for reaction studies with RIBs in reverse kinematics; Canadian Penning Trap for precision mass measurements
  - HRIBF: High Power Target Laboratory and Injector for Radioactive Ion Species 2; new endstation for study of rare isotopes including beta-delayed neutron decay; ORRUBA spectrometer for proton reactions with rare isotope beams (in collaboration with Rutgers/NNSA)
- **User Community:**
  - $\sim 700$  users including international and NSF-supported researchers
- **Core Capabilities:**
  - ATLAS: Superconducting Radiofrequency technology for heavy ion accelerators; gas cell heavy ion catchers
  - HRIBF; development of ISOL technology for radioactive ion beams



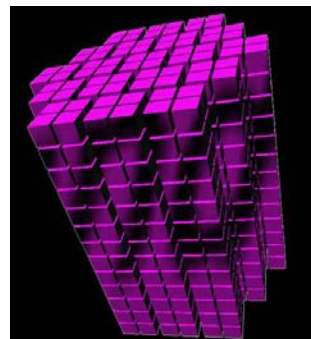
**HRIBF**  
**Re-accelerates**  
**Rare Isotope Beams**

# Research and Experiments with Neutrinos

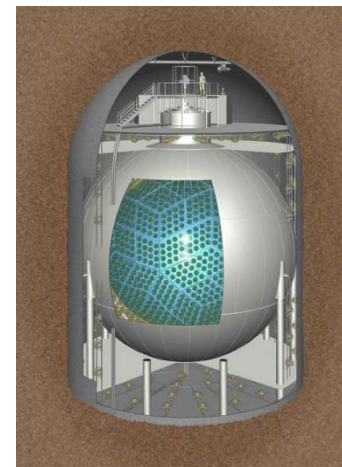
NP plays a key role in the studies of neutrinos including understanding their oscillation properties, assessing their particle/anti-particle nature, and determining their masses

- NP researchers collaborate on three neutrino experiments and one R&D project:
  - Upgraded KamLAND to measure low energy solar neutrinos
  - CUORE to search for neutrino-less double beta decay
  - KATRIN to determine the neutrino mass (down to  $\sim 300$  meV) by measuring the shape of the tritium beta decay spectrum
  - Majorana Demonstrator R&D to determine the feasibility of a germanium-based neutrino-less double beta decay experiment (Majorana is a candidate to be sited at DUSEL)

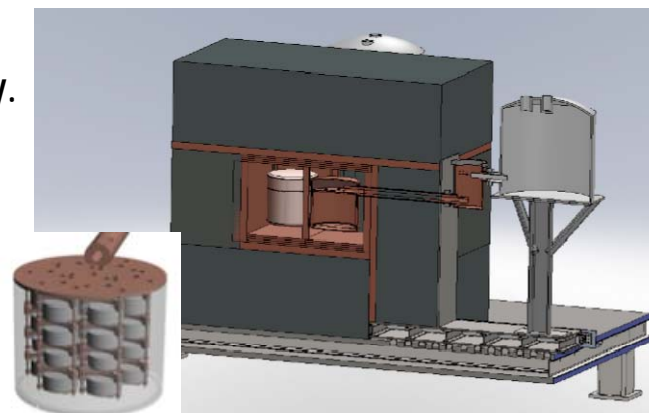
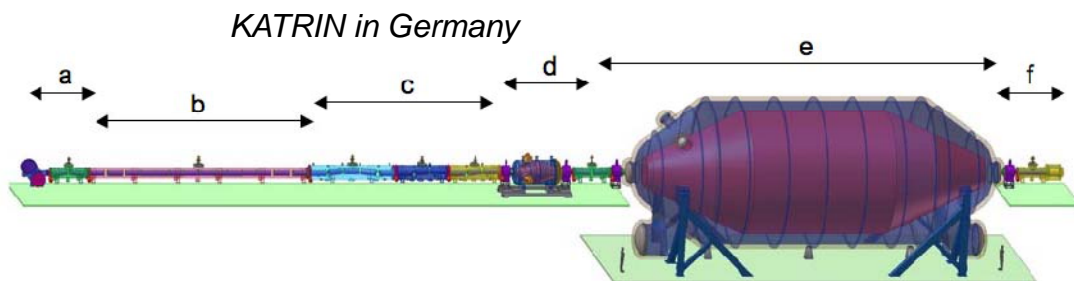
A DUSEL Joint Oversight Group organized by NSF, HEP, and NP coordinates activities related to the research program at the facility.



*CUORE in Italy*



*KamLAND in Japan*



*Majorana Demonstrator*



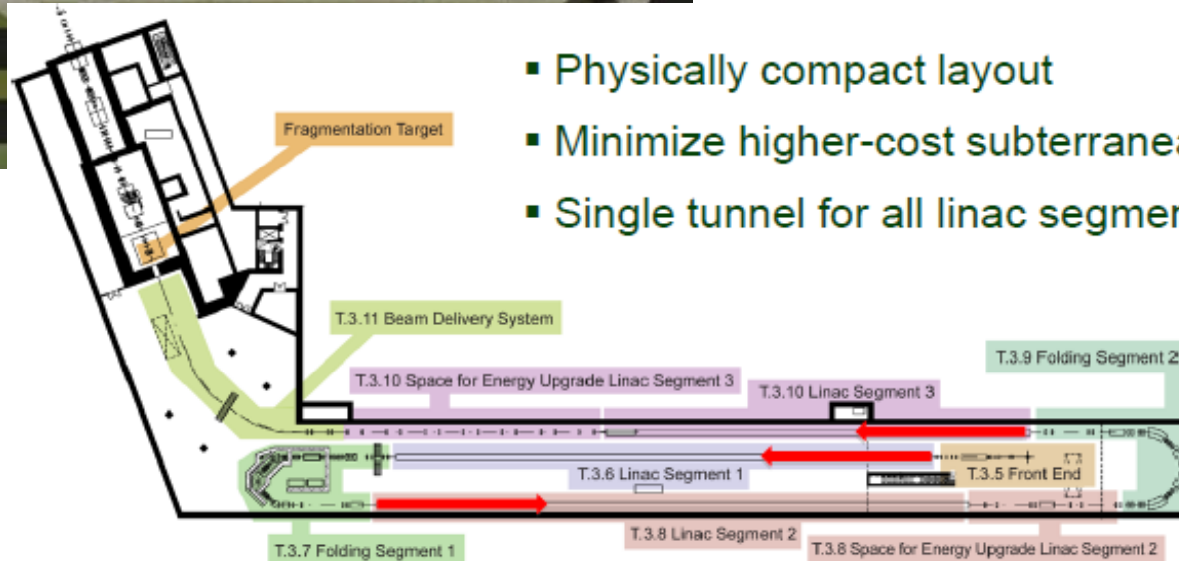


# The Facility for Rare Isotope Beams



Lehman review of readiness  
for CD1 July 27-29, 2010

ESAAB August 31, 2010  
Project receives CD-1



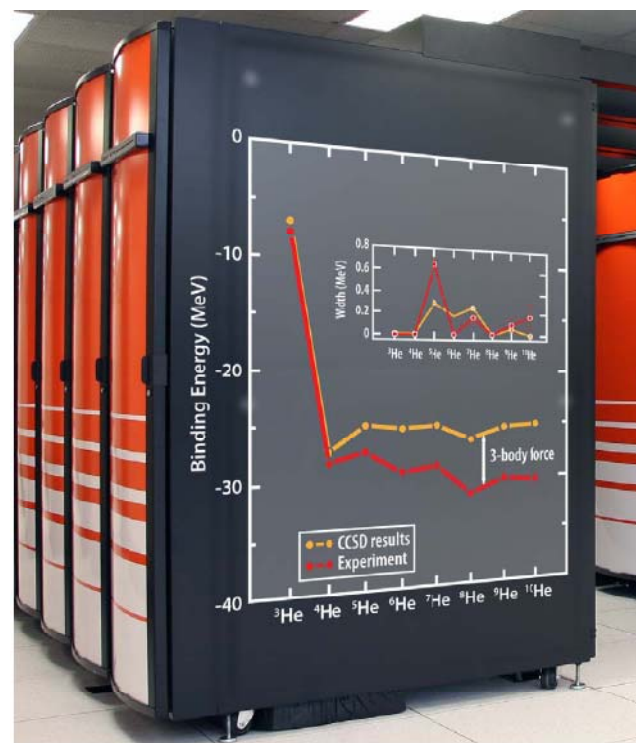
- Physically compact layout
- Minimize higher-cost subterranean structures
- Single tunnel for all linac segments

# Theory Subprogram

- Addresses all three of the field's scientific frontiers
  - Quantum chromodynamics
  - Nuclei and Nuclear Astrophysics
  - Fundamental Symmetries and Neutrinos
- The Nuclear Data Program activities are within this subprogram
  - Compilation, evaluation, and dissemination of nuclear structure and reaction data
  - Coordination with international nuclear data activities

## ***Three body forces required to calculate the masses of heavy Helium nuclei***

- *Ab initio* calculations of Helium masses carried out as part of SciDAC-2 show a systematic deviation compared to those measured
- Deviation attributed to three-body forces missing in these calculations
- Coupled cluster calculations are being carried out for medium mass nuclei with up to 40 and 48 protons and neutrons





# Components of the IDPRA Subprogram

- **Research groups supported at national laboratories and universities**
  - Limited research and development provides improved isotope production and processing
  - The 2009 Appropriation re-established a research and develop effort and the production of research isotopes
  - Reduces dependence on foreign supplies, affordable isotopes for research, meet present and future researchers' needs for isotopes
- **Operations for isotope production**
  - Stewardship of Brookhaven Linear Isotope Producer (BLIP) at BNL
  - Stewardship of Isotope Production Facility (IPF) at LANL
  - Isotope production at reactors at ORNL and INL
  - Hot cell facilities at BNL, ORNL, LANL, others
  - National Isotope Data Center (NIDC)--management information center for all national laboratories and universities in the subprograms portfolio of processing and production of isotopes
- **Technical activities**
  - Production, processing, packaging and transportation of radioisotopes
  - R&D includes target fabrication, enhance processing techniques, radiochemistry, material conversions, new production techniques
  - Sales of and services for stable isotopes from stockpile

