2010 Decadal Review of Nuclear Physics

An Assessment and Outlook for Nuclear Physics

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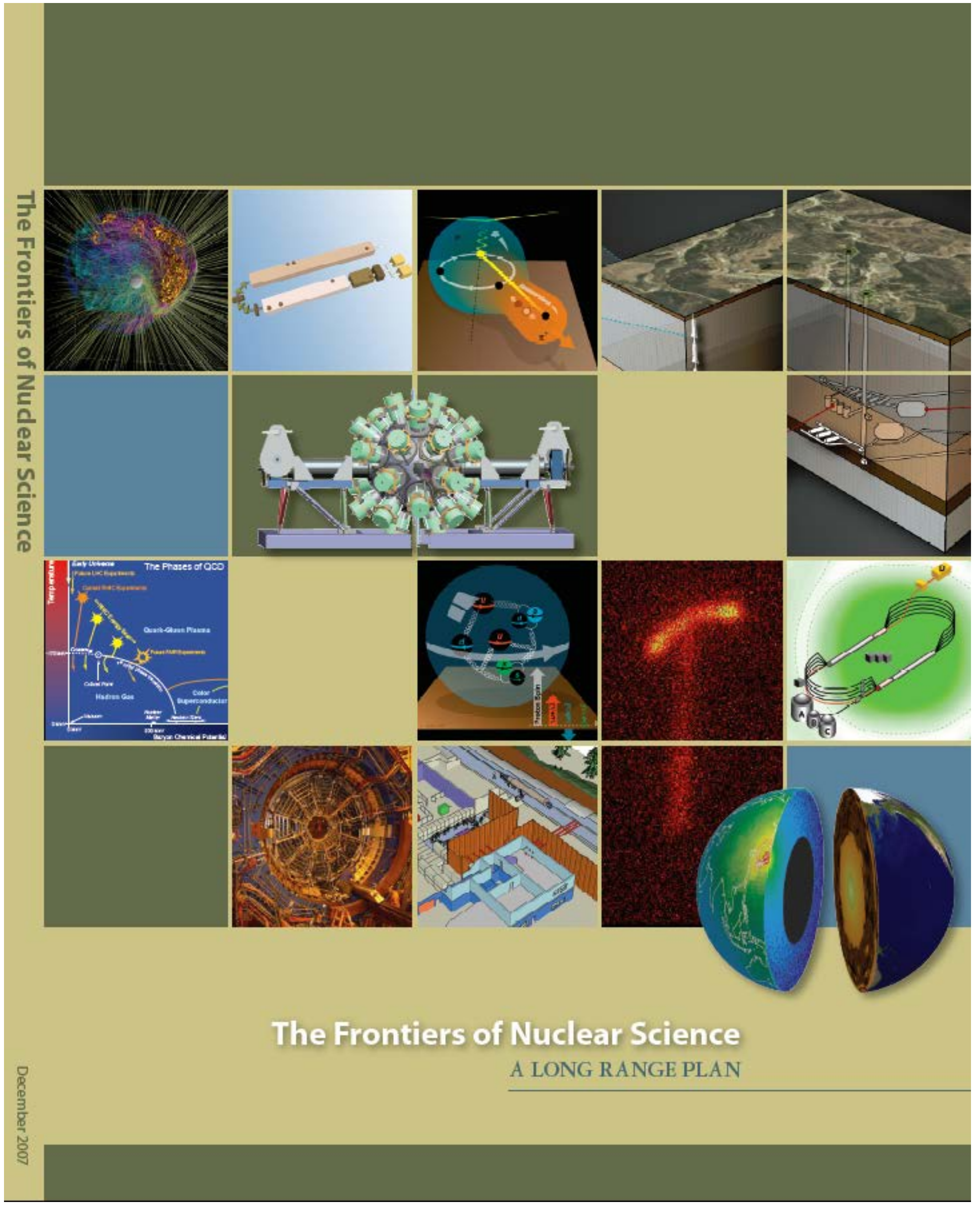
NP2010 Statement of Task

Statement of Task:

The new 2010 NRC decadal report will prepare an assessment and outlook for nuclear physics research in the United States in the international context. The first phase of the study will focus on developing a clear and compelling articulation of the scientific rationale and objectives of nuclear physics. This phase would build on the 2007 NSAC Long-range Plan Report, placing the near-term goals of that report in a broader national context.

The second phase will put the long-term priorities for the field (in terms of major facilities, research infrastructure, and scientific manpower) into a global context and develop a strategy that can serve as a framework for progress in U.S. nuclear physics through 2020 and beyond. It will discuss opportunities to optimize the partnership between major facilities and the universities in areas such as research productivity and the recruitment of young researchers. It will address the role of international collaboration in leveraging future U.S. investments in nuclear science. The strategy will address means to balance the various objectives of the field in a sustainable manner over the long term.

2007 NSAC Long Range Plan



A five year plan organized and formulated by the community through NSAC, advising DOE & NSF on science & development priorities in Nuclear Physics!

- ❑ Selecting organizing & writing committees
- ❑ Town meetings for sub-communities
- ❑ NSAC meeting for entire community
- ❑ Write-up of report
- ❑ Presentation of report to NSAC
- ❑ Presentation of report to agencies

Nuclear Physics Program in the U.S.

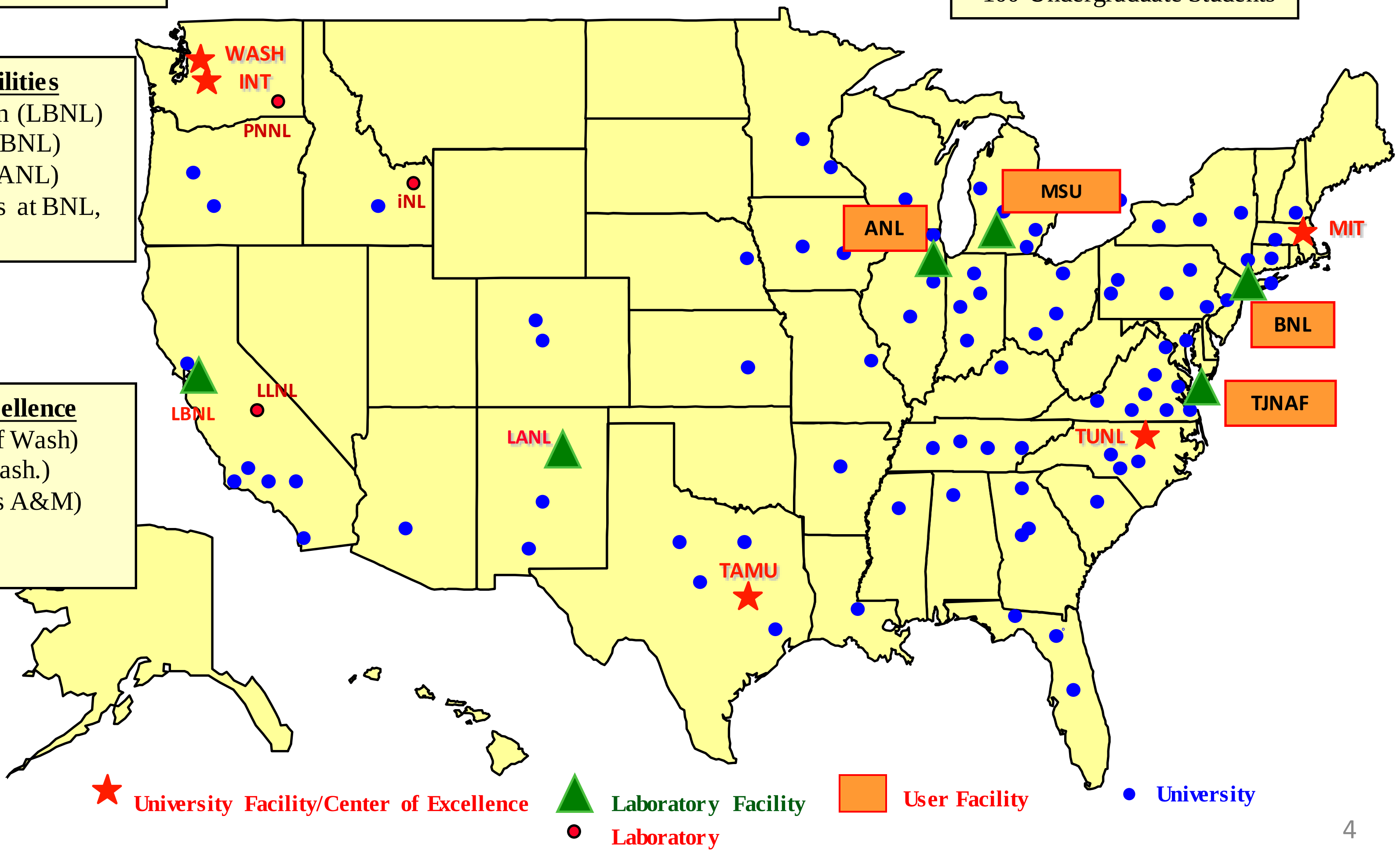
National User Facilities
- RHIC (BNL) - DOE
- CEBAF (TJNAF) - DOE
- ATLAS (ANL) - DOE
- NSCL (MSU) - NSF

Research Groups
- 9 National Laboratories
- 85 Universities

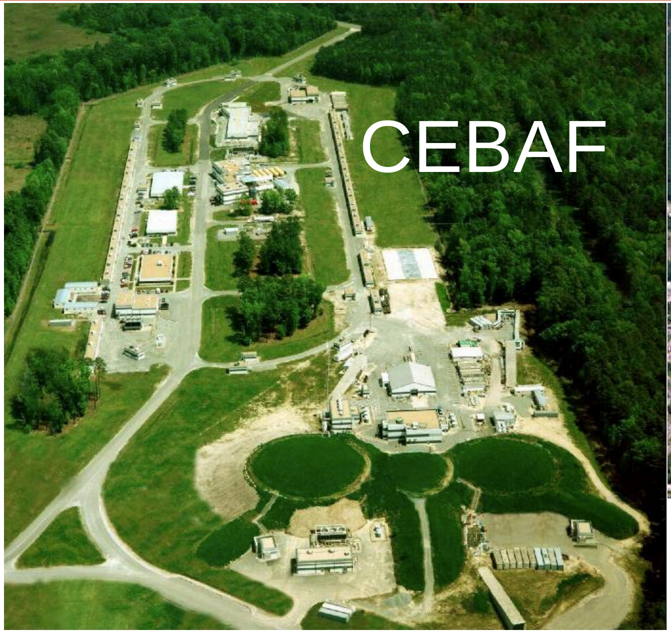
NP Workforce
~720 Faculty & Lab Res Staff
~400 Post-docs
~500 Graduate Students
~100 Undergraduate Students

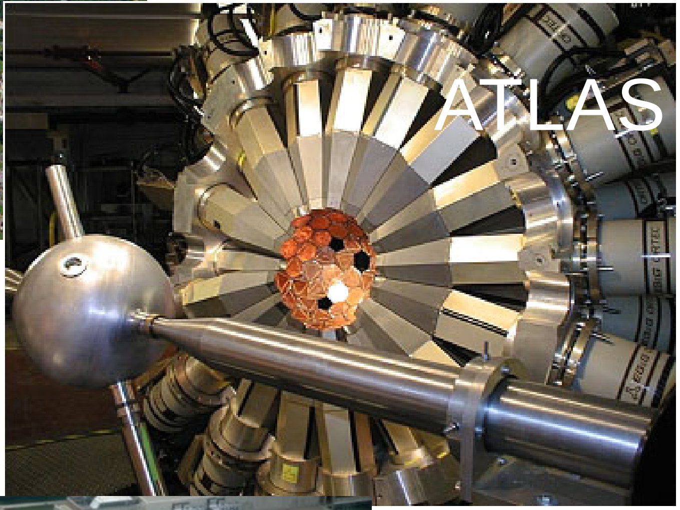
Other Lab. Facilities
- 88-Inch Cyclotron (LBNL)
- 200 MeV BLIP (BNL)
- 100 MeV IPF (LANL)
- Hot Cell Facilities at BNL, LANL, ORNL

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



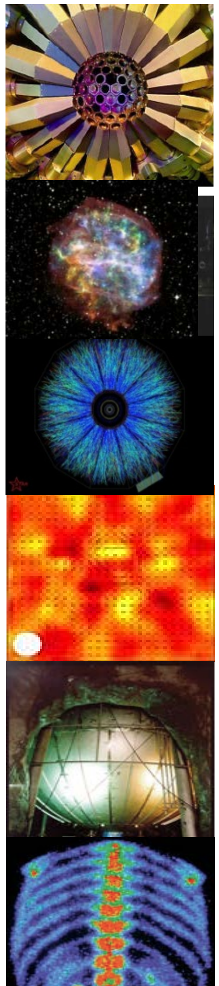
Facilities





- 4 National User Facilities
- Approximately 40% of users are from foreign institutions
- After completion FRIB will be a major National User Facility

Exploring the Heart of Matter

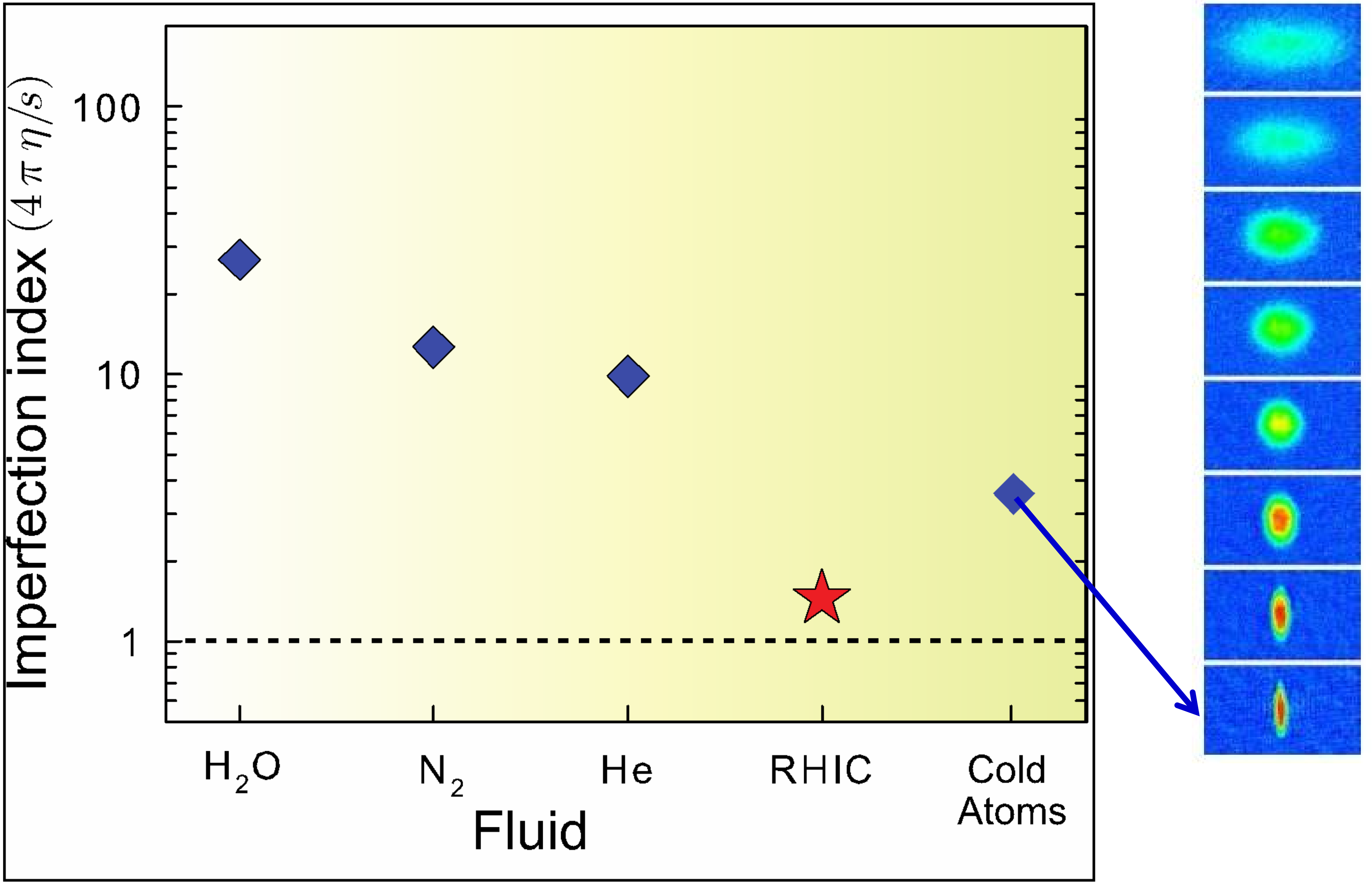


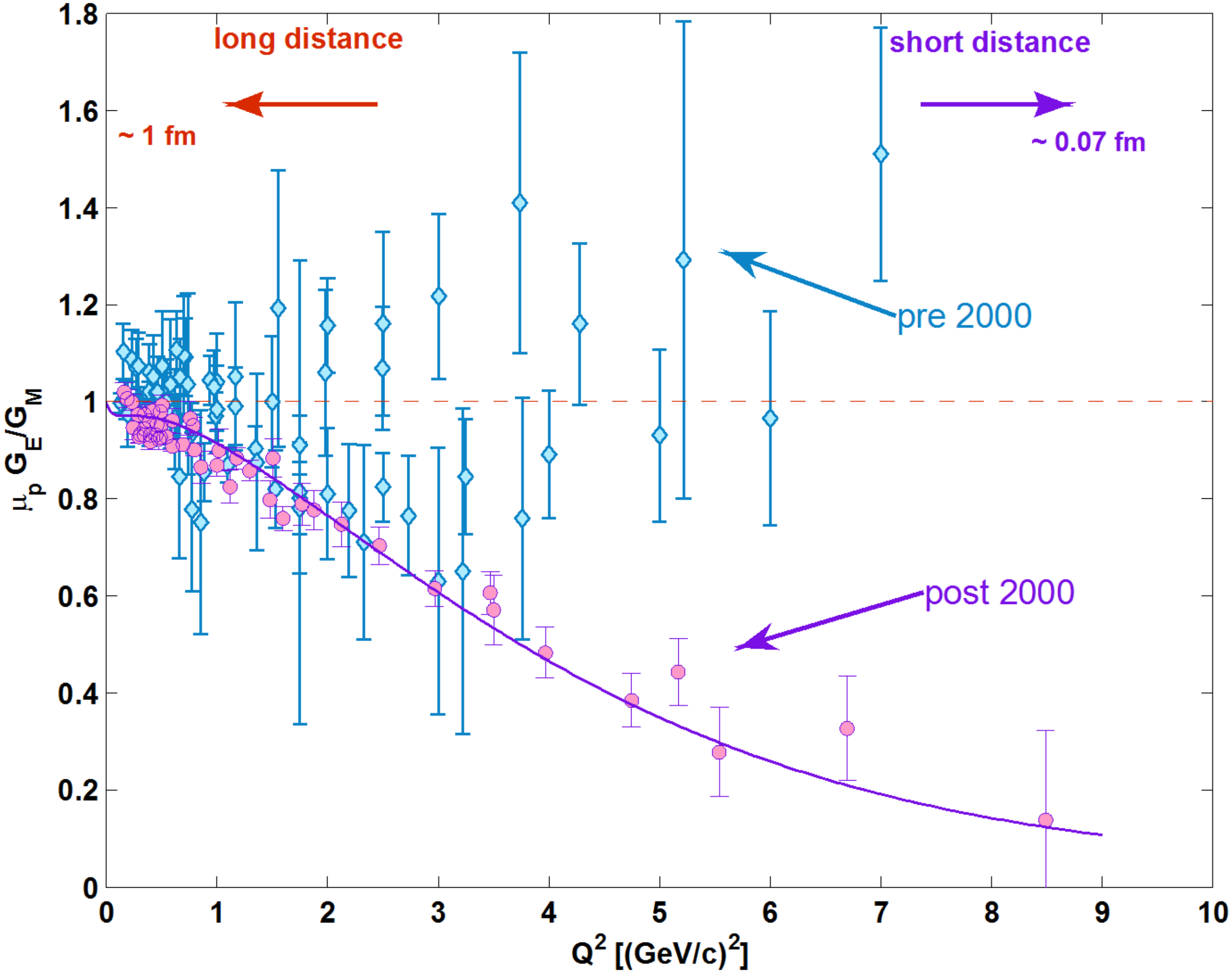
- Structure of Atomic Nuclei
- Nuclear Astrophysics
- Quark Gluon Plasma
- Quark Structure of the Nucleon
- Fundamental Symmetries
- Nuclear Physics Applications

Major Accomplishments Since 1999

- Discovery of a near perfect fluid in relativistic heavy-ion collisions at RHIC
- Precision determination of the electric and magnetic form factors of the proton and neutron at Jlab
- Final resolution of the Solar Neutrino Problem and direct evidence for neutrino oscillations with SNO and KamLAND

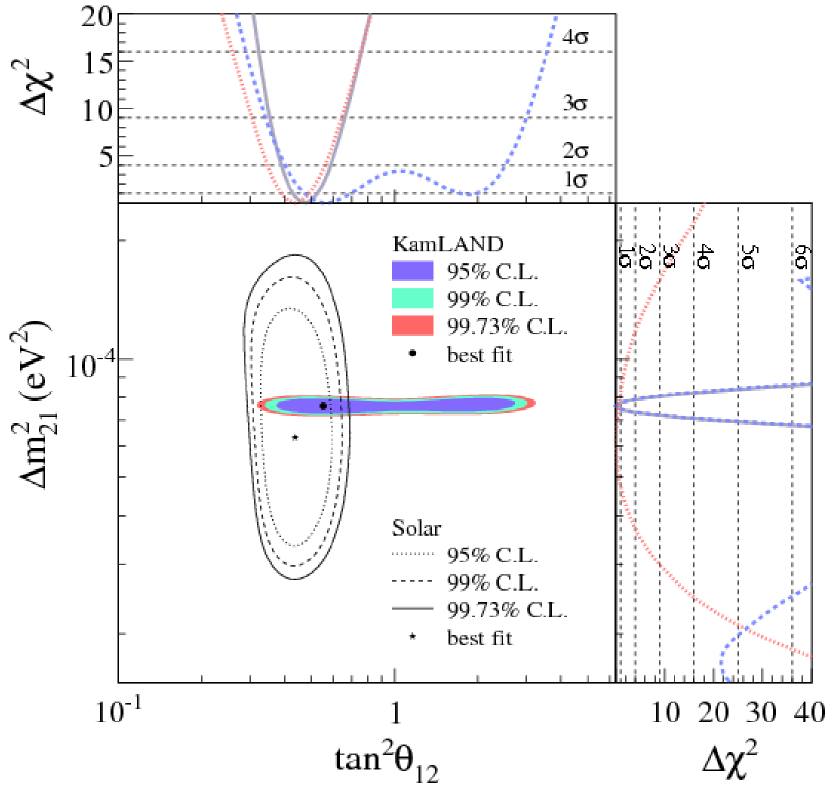
Quantifying Perfection



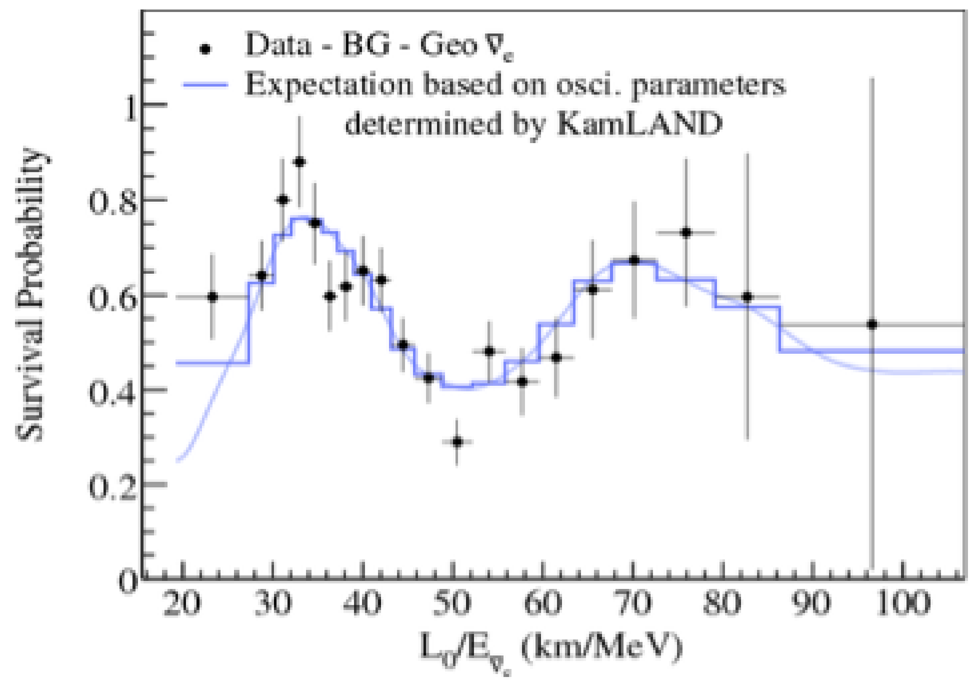


Magnetic and Electric distribution of charge is different in the proton

Solar Neutrino Problem Solved
Neutrino Oscillations Established

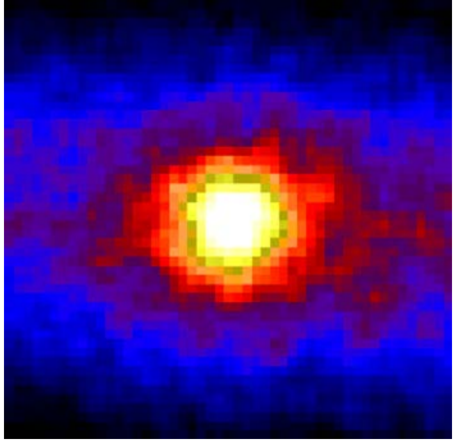


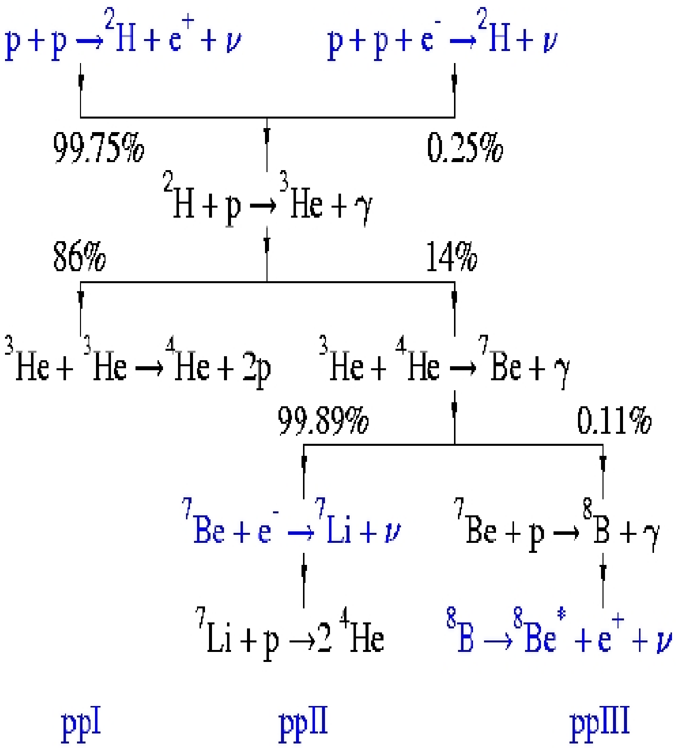
Constraints on neutrino oscillation parameters from SNO and KamLAND

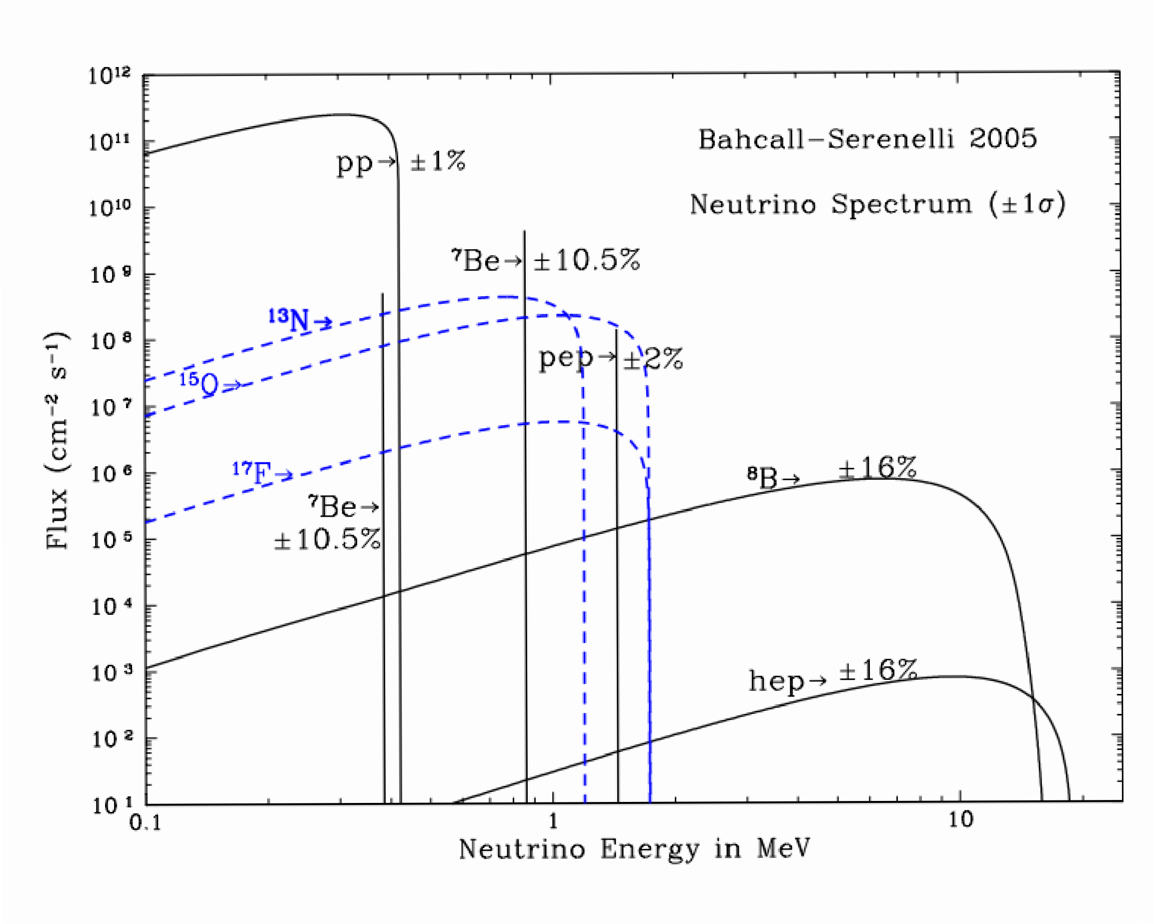


"Direct" observation of neutrino oscillations from KamLAND

Solar Neutrinos







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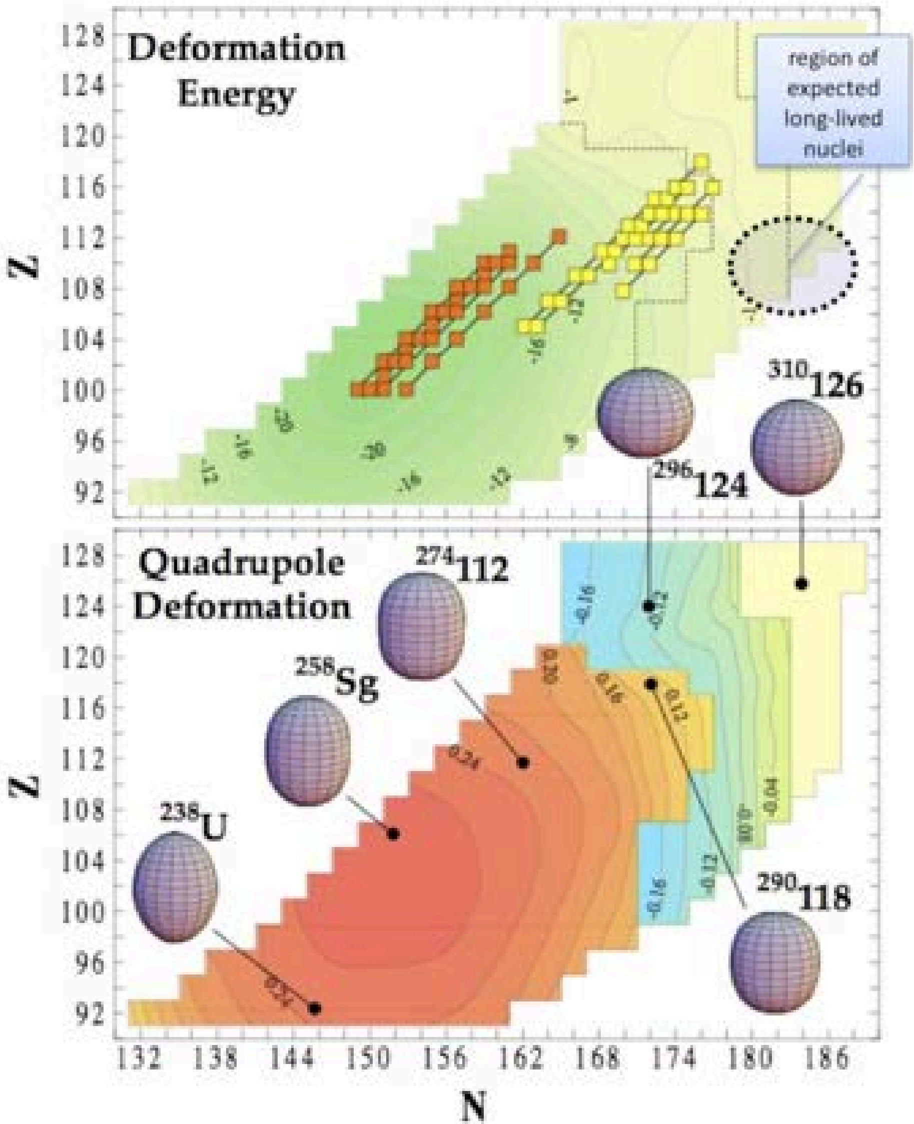
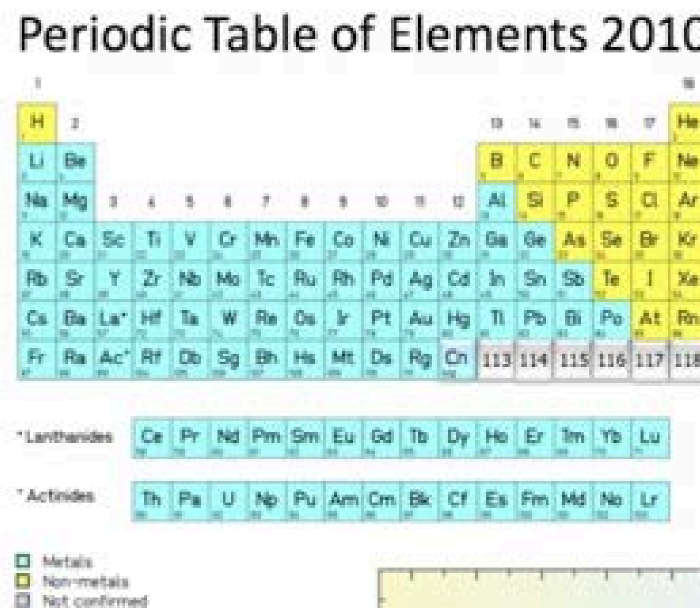
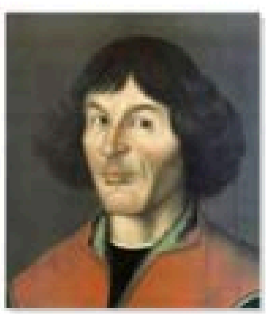
Physics of Superheavy Elements

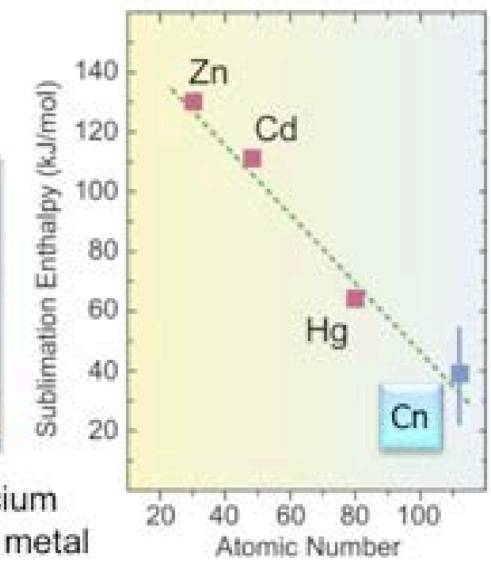


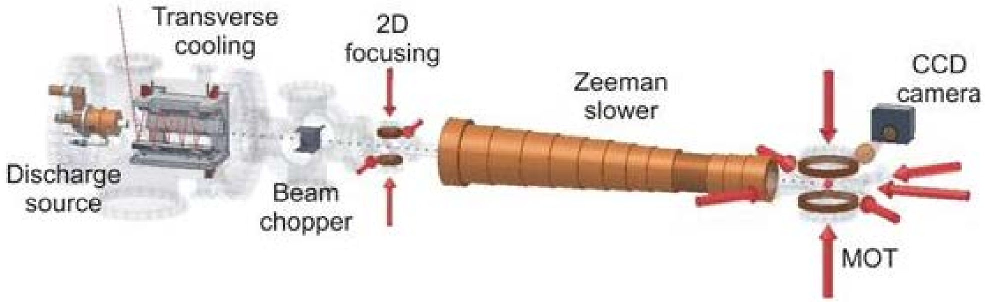
Chemistry of Superheavy Elements



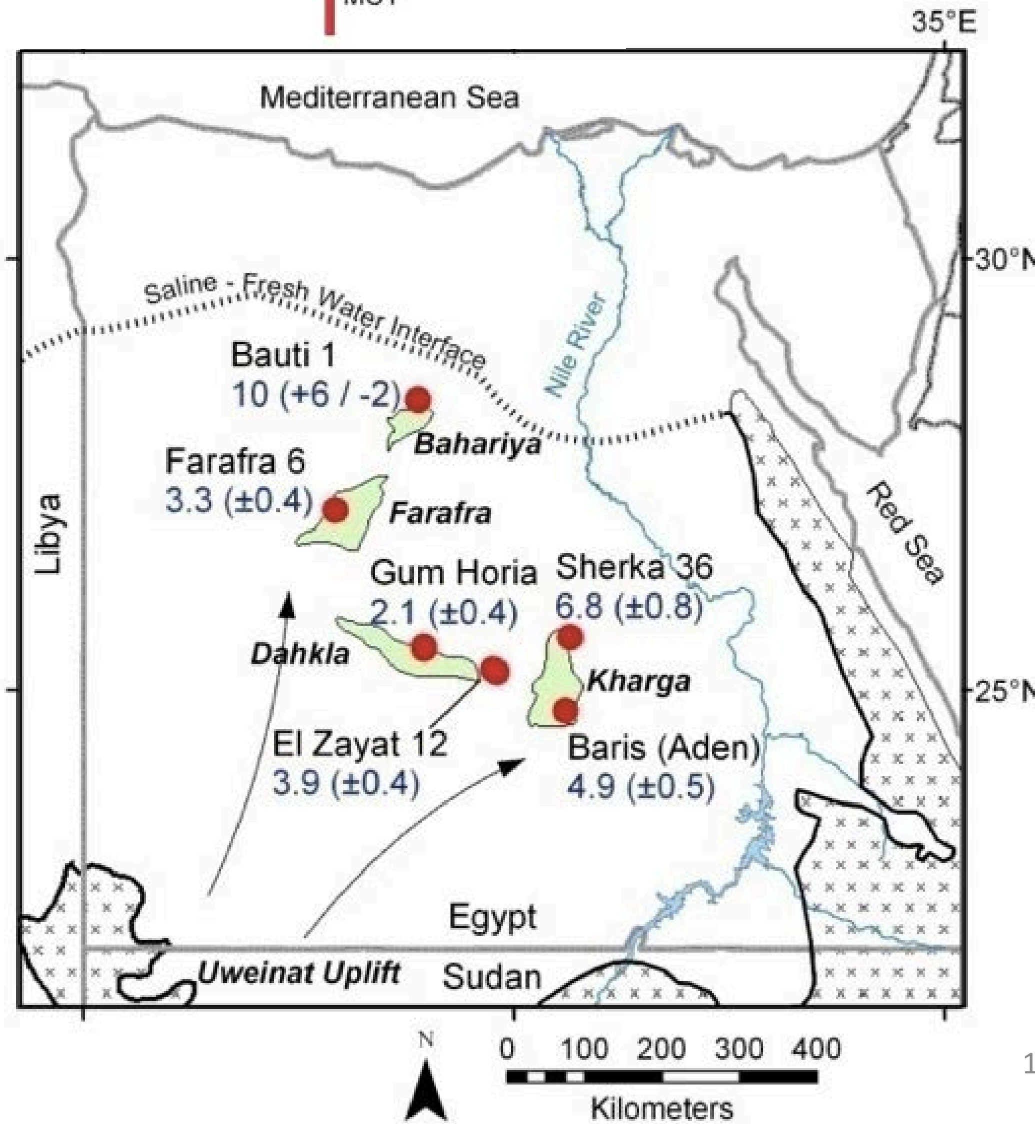


Z=112: Copernicium
very volatile noble metal

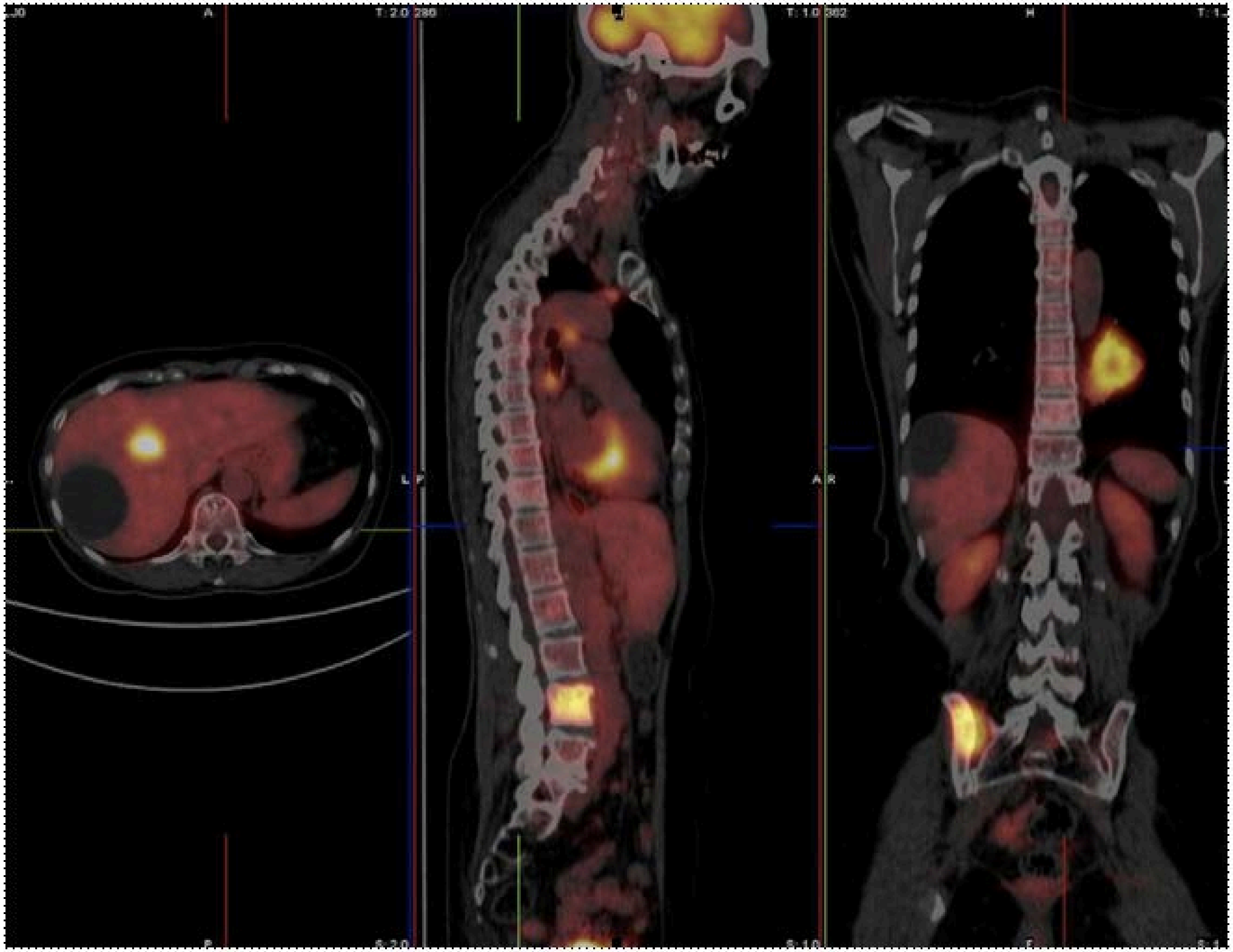




New techniques for trace element analysis with single trapped atoms



New and improved imagining techniques



Statement of Task (Abbreviated)

- **What are the scientific rationale and objectives of nuclear physics?**

- **Develop a long term strategy for US nuclear physics into 2020 in the global context.**

  - **Place the near term goals of the 2007 LRP in a broader national context.**
  - **Discuss the strategy to optimize the partnership between facilities and universities.**
  - **Address the role of international collaboration in leveraging future US investments.**

Exploitation of current opportunities

Finding: By capitalizing on strategic investments, including the ongoing upgrade of CEBAF and the recently completed upgrade of RHIC, as well as other upgrades to the research infrastructure, nuclear physicists will confront new opportunities to make fundamental discoveries and lay the groundwork for new applications.

Conclusion: Exploiting strategic investments should be an essential component of the U.S. nuclear science program in the coming decade.

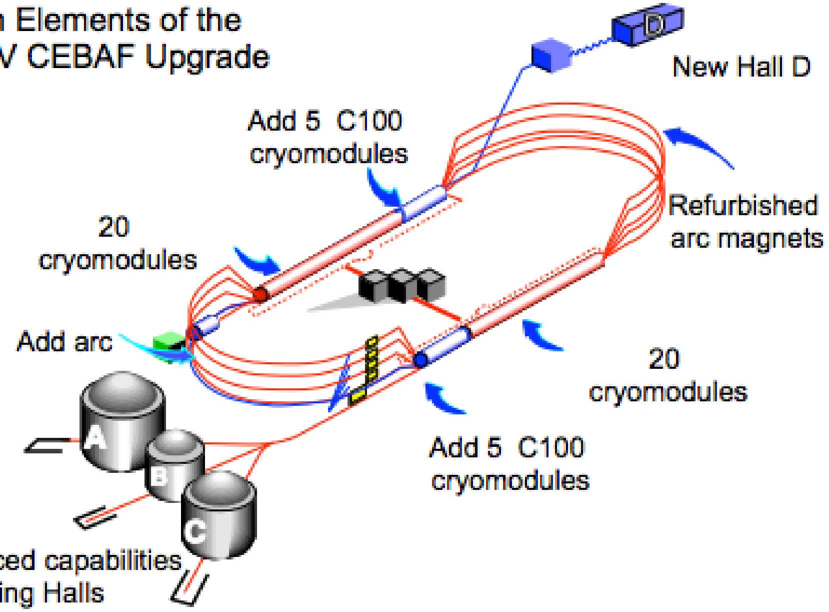
The JLaB 12 GeV Up-Grade

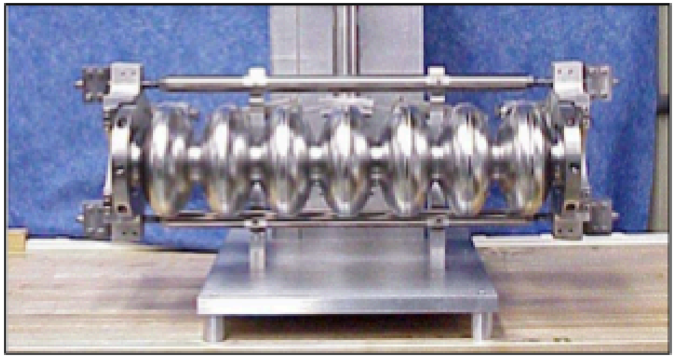
The 12 GeV CEBAF Upgrade at TJNAF is 60% Complete

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

- The search for exotic new quark-anti-quark particles to advance our understanding of the strong force
- Evidence of new physics from sensitive searches for violations of nature's fundamental symmetries
- A detailed microscopic understanding of the internal structure of the proton, including the origin of its spin, and how this structure is modified when the proton is inside a nucleus

Main Elements of the 12 GeV CEBAF Upgrade





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

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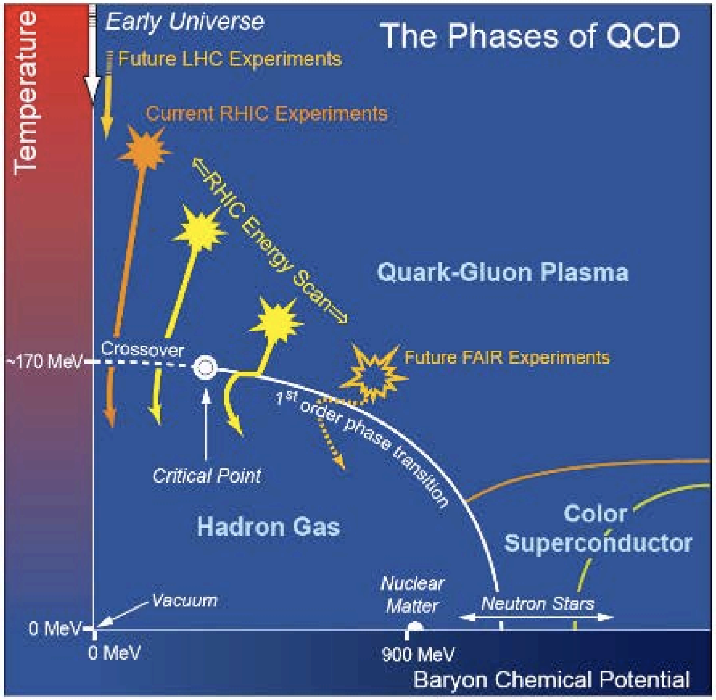
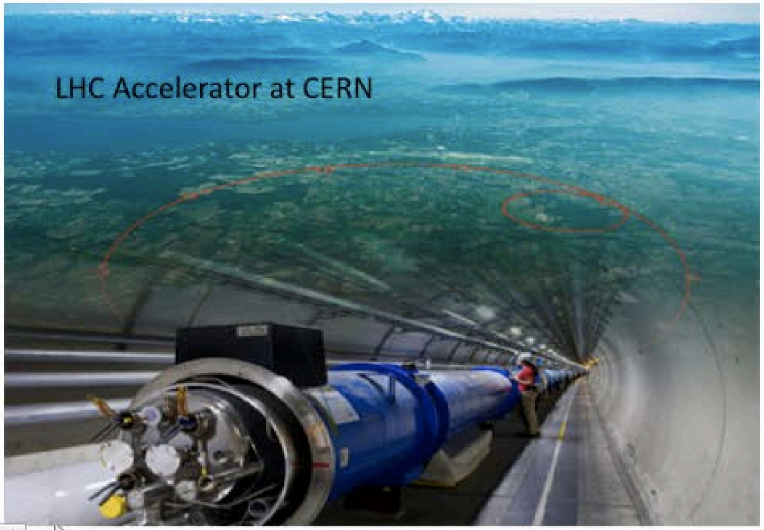
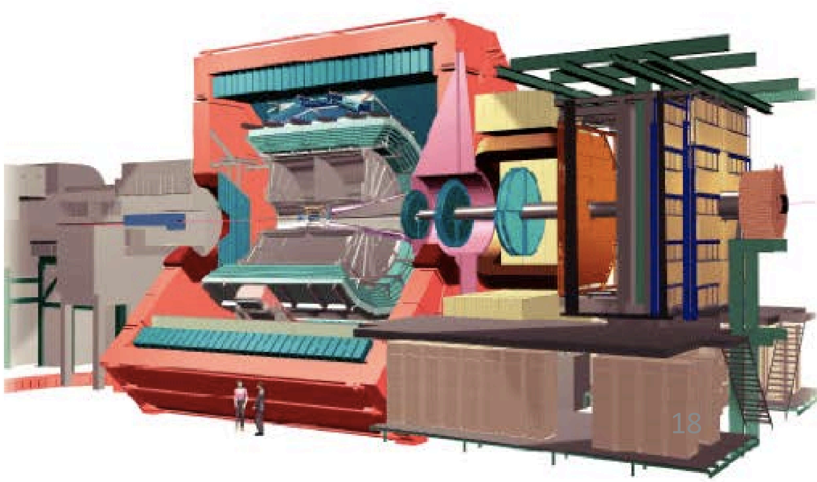
- Up-grade of PHENIX & STAR
- Increase of RHIC luminosity
- US participation in heavy ion program at LHC at CERN with the detectors ALICE
- Relativistic heavy ion beam experiments at FAIR/GSI







The Facility for Rare Isotope Beams

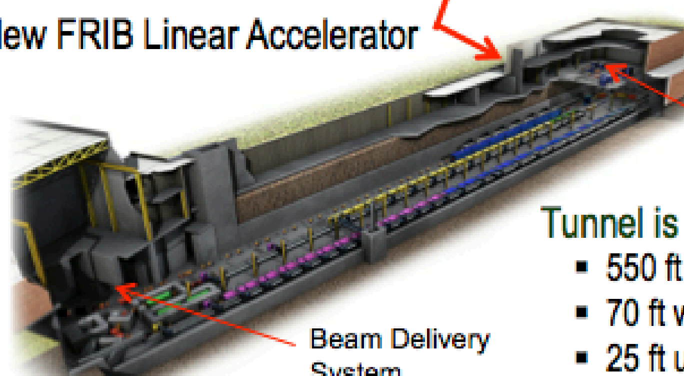
Finding: The Facility for Rare Isotope Beams is a major new strategic investment in nuclear science. It will have unique capabilities and offers opportunities to answer fundamental questions about the inner workings of the atomic nucleus, the formation of the elements in our universe, and the evolution of the cosmos.

Recommendation: The Department of Energy's Office of Science, in conjunction with the State of Michigan and Michigan State University, should work toward the timely completion of the Facility for Rare Isotope Beams and the initiation of its physics program.

Preparations for Construction of Facility for Rare Isotope Beams

Existing National Superconducting Cyclotron Laboratory

New FRIB Linear Accelerator



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

FRIB will increase the number of isotopes with known properties from ~2,000 observed over the last century to ~5,000 and will provide world-leading capabilities for research on:

Nuclear Structure
- The ultimate limits of existence for nuclei
- Nuclei which have neutron skins
- The synthesis of super heavy elements

Nuclear Astrophysics
- The origin of the heavy elements and explosive nucleo-synthesis
- Composition of neutron star crusts

Fundamental Symmetries
- Tests of fundamental symmetries, Atomic EDMs, Weak Charge

This research will provide the basis for a model of nuclei and how they interact.

Underground science in the United States

Recommendation: The Department of Energy, the National Science Foundation and other funding agencies where appropriate should develop and implement a targeted program of underground science, including important experiments on whether neutrinos differ from antineutrinos, what is dark matter, and nuclear reactions of astrophysical importance. Such a program would be substantially enabled by the realization of a deep underground laboratory in the United States.

Nuclear Physics at Universities

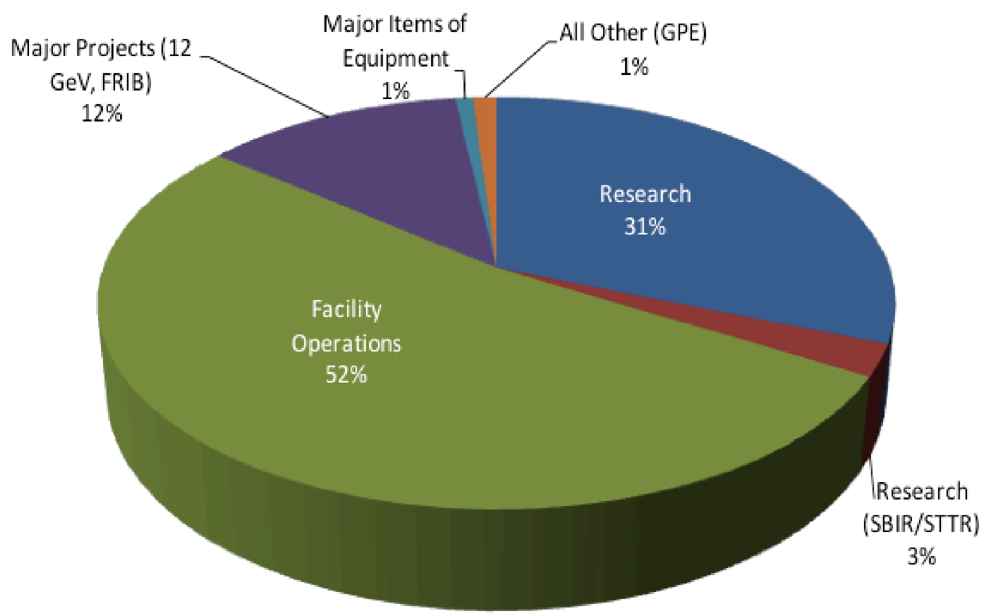
Finding: The dual roles of universities, education and research, are important in all aspects of nuclear physics including the operation of small, medium, and large scale facilities, as well as the design and execution of large experiments at national research laboratories. The vitality and sustainability of the U.S. nuclear physics program depend in an essential way on the intellectual environment and the workforce provided symbiotically by universities and national laboratories. The fraction of the nuclear science budget reserved for facilities operations cannot continue to grow at the expense of the resources available to support research without serious damage to the overall nuclear science program.

Conclusion: In order to ensure the long-term health of the field, it is critical to establish and maintain a balance between funding of major facilities operations and the needs of university-based programs.

FY 2013 Congressional Request
Nuclear Physics by Major Category

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

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



FY 2013 Congressional Request
Total = $526.9M

Nuclear physics and exascale computing

Recommendation: A plan should be developed within the theoretical community and enabled by the appropriate sponsors that permits forefront-computing resources to be deployed by nuclear science researchers and establishes the infrastructure and collaborations needed to take advantage of exascale capabilities as they become available.

Striving to be Competitive and Innovative

Finding: The scale of projects in nuclear physics covers a broad range, and sophisticated new tools and protocols have been developed for successful management of the largest of them. At the other end of the scale, nimbleness is essential if the United States is to remain competitive and innovative in a rapidly expanding international nuclear physics activity.

Recommendation: Streamlined and flexible procedures should be developed within the sponsoring agencies that are tailored for initiating and managing smaller scale nuclear science projects.

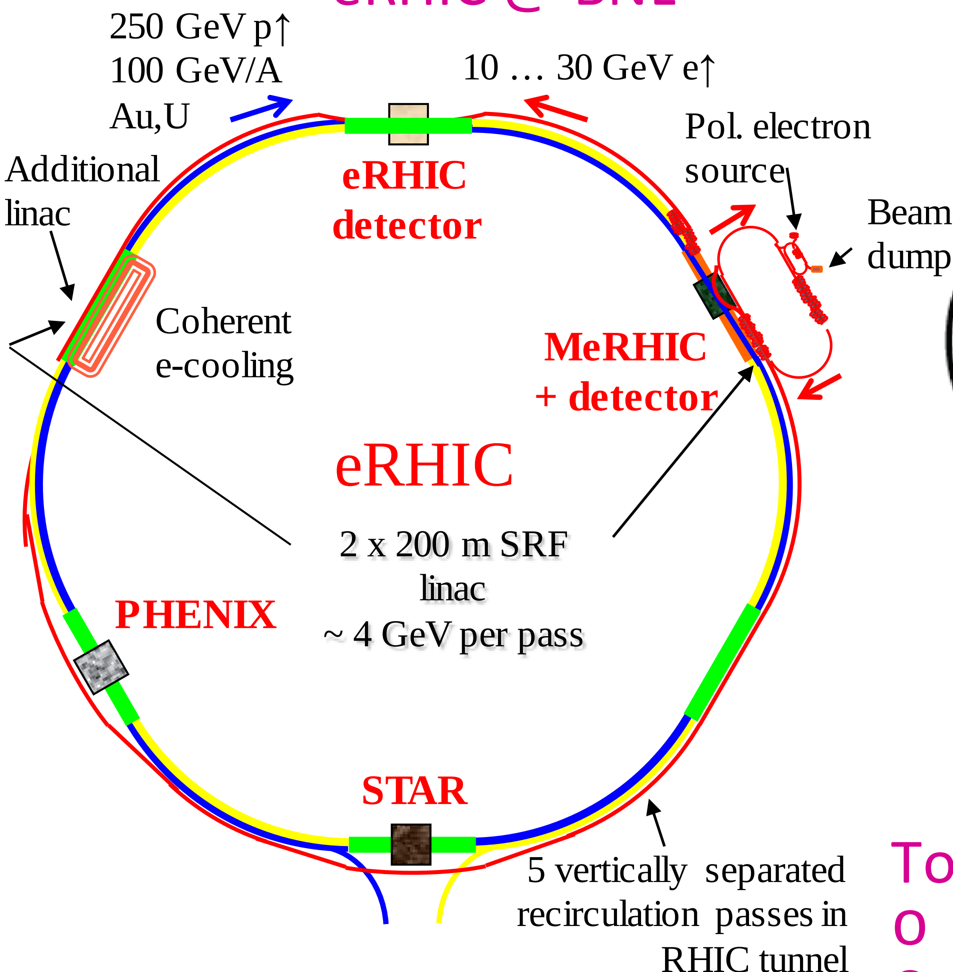
The prospects of an electron-ion collider

Finding: An upgrade to an existing accelerator facility providing the capability of colliding nuclei and electrons at forefront energies would be unique for studying new aspects of quantum chromodynamics and, in particular, would yield new information on the role of gluons in protons and nuclei. An electron-ion collider is currently a subject of study as a possible future facility

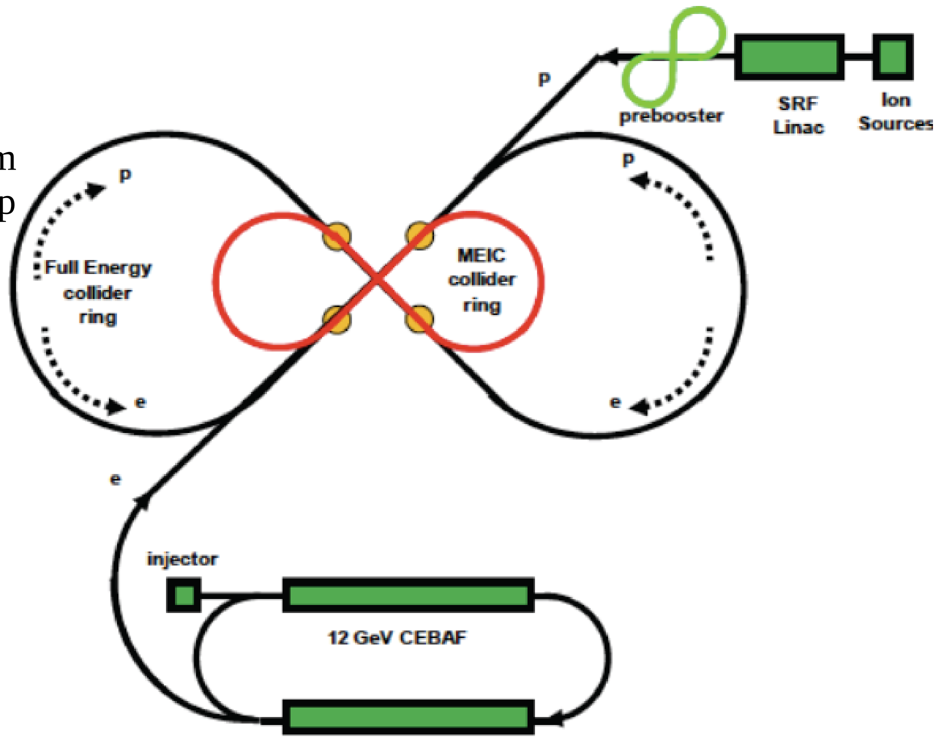
Recommendation: Investment in accelerator and detector research and development for an electron-ion collider should continue. The science opportunities and the requirements for such a facility should be carefully evaluated in the next Nuclear Science Long Range Plan.

Future Facilities

MeRHIC and eRHIC @ BNL



MEIC and EIC @ JLab



To Investigate:

- The gluon structure of matter
- The 3D structure of hadrons
- Physics beyond the Standard Model

Thank You!

The report and videos that accompanied its release can be found here - http://sites.nationalacademies.org/BPA/BPA_069589