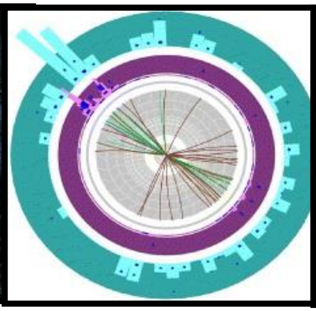
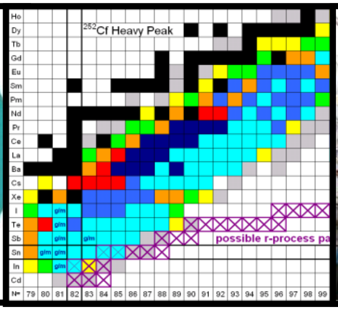
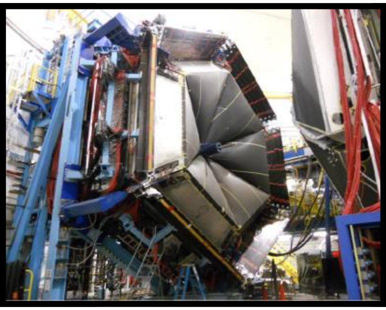
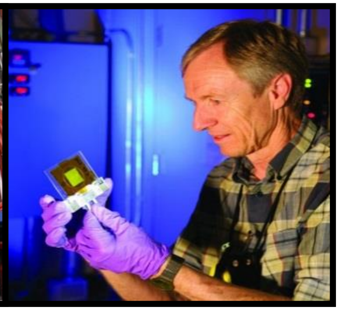
Perspectives from DOE NP

Nuclear Science Advisory Committee Meeting

March 12, 2018

Dr. T. J. Hallman
Associate Director for Nuclear Physics
DOE Office of Science

Budget News

FY 2019 SC Budget Request

(Dollars in Thousands)

	FY 2017		FY 2018				FY 2019		
	Enacted Approp.	Current Approp.	President's Request	House Mark	Senate Mark	Annualized CR [b]	President's Request	President's Request vs. FY 2017 Enacted	
ASCR	647,000	626,559	722,010	694,200	763,000	642,606	899,010	252,010	38.95%
BES	1,871,500	1,812,113	1,554,500	1,871,500	1,980,300	1,858,791	1,850,000	-21,500	-1.15%
BER	612,000	588,826	348,950	582,000	633,000	607,844	500,000	-112,000	-18.30%
FES	380,000	368,119	309,940	395,000	232,000	377,419	340,000	-40,000	-10.53%
HEP	825,000	802,849	672,700	825,000	860,000	819,397	770,000	-55,000	-6.67%
NP	622,000	604,473	502,700	619,200	639,200	617,776	600,000	-22,000	-3.54%
WDTS	19,500	19,500	14,000	19,500	19,500	19,368	19,000	-500	-2.56%
SLI	130,000	130,000	76,200	105,600	143,000	129,117	126,852	-3,148	-2.42%
S&S	103,000	103,000	103,000	103,000	103,000	102,301	106,110	3,110	3.02%
PD	182,000	182,000	168,516	177,000	177,000	180,764	180,000	-2,000	-1.10%
SBIR/STTR (SC)	......	154,561	......	......	......	......	......	......	......
Subtotal, Science	5,392,000	5,392,000	4,472,516	5,392,000	5,550,000	5,355,383	5,390,972	-1,028	-0.02%
SBIR/STTR (DOE)	......	90,813	......	......	......	......	......	......	......
Rescission of PY Bal [a]	-1,028	-1,028	......	......	......	-1,021	......	1,028	-100.00%
Total, Science	**5,390,972**	**5,481,785**	**4,472,516**	**5,392,000**	**5,550,000**	**5,354,362**	**5,390,972**	**......**	......

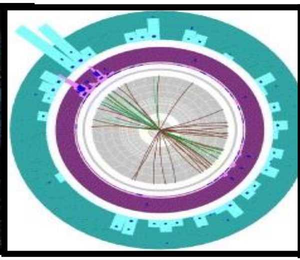
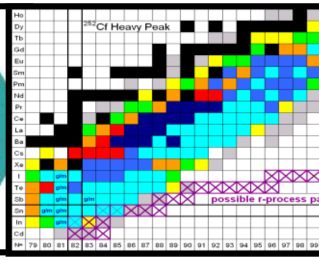
[a] *Rescission of PY funds in the amount -$239M for FY 2012 and older; -$239M for FY 2013; and -$550M for FY 2014 - FY 2016.*

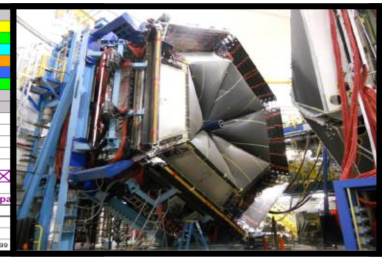
[b] *FY 2018 Annualized CR column is based on the FY 2017 Enacted minus a 0.6791% reduction totaling $36.617M*

Nuclear Physics

Discovering, exploring, and understanding all forms of nuclear matter

- Funding for research focuses resources on the highest priority nuclear science research in relativistic nuclear collisions, hadron physics, nuclear structure and nuclear astrophysics, and fundamental symmetries.
- Operations at RHIC are supported for 19 weeks in FY 2019 to search for a critical point in the phase diagram of nuclear matter. The sPHENIX MIE is initiated within current RHIC funding levels for precision, high rate particle jets studies.
- The 12 GeV CEBAF Upgrade, completed in FY 2017, continues its scientific program with a 19 week run in FY 2019 promising new discoveries and an improved understanding of quark confinement.
- Funding for ATLAS supports 34 weeks of operations, to provide high-quality beams of all the stable elements up to uranium, as well as selected beams of short-lived nuclei for nuclear structure and astrophysics experiments.
- Construction continues on the Facility for Rare Isotope Beams. The Gamma-Ray Energy Tracking Array (GRETA) MIE is continued to exploit the scientific potential of FRIB.
- A Nuclear Physics Quantum Information Science (QIS) effort is initiated to support NP experiments and modeling, as well as the production of critical isotopes for quantum computing.
- Increased funding for the Isotope Program supports the Stable Isotope Production Facility (SIPF) MIE to produce kilogram quantities of enriched stable isotopes, mission readiness of radioisotope production facilities, and the initiation of a university production network for short-lived isotopes and QIS.




Nuclear Physics – Research

	FY17 Enacted	FY18 Annualized CR	FY19 President's Request	FY19 vs. FY17
Medium Energy	35,334	36,954	33,487	-1,847
Heavy Ions	38,035	37,006	34,017	-4,018
Low Energy	56,169	56,761	52,560	-3,609
Theory (less Quantum)	44,297	43,507	42,847	-1,450
Theory, Quantum	-	-	6,800	+6,800
Isotope Program	8,829	8,579	8,829	-
Total	**182,664**	**182,807**	**178,540**	**-4,124**

The FY 2019 President's Request reflects a continued commitment to research, including a new focus on Quantum Information Sciences.

- **Medium Energy**: Implement the 12 GeV physics research program to advance understanding of strongly interacting matter and search for evidence of new physics beyond the Standard Model; determine the origin of the spin of the proton.
- **Heavy Ions**: Explore newly discovered phenomena in quark gluon plasma formation at RHIC and the LHC, and elucidate broader intellectual connections and impacts in other fields of science.
- **Low Energy**: Develop and implement instrumentation to advance knowledge in nuclear structure and astrophysics at ATLAS and FRIB; carry out research in fundamental symmetries and neutrons, including R&D towards a ton-scale experiment to determine if the neutrino is its own antiparticle.
- **Theory**: Support theoretical research to advance knowledge across nuclear science; expand a collaborative theory effort on FRIB science, as well as continue the new cohort of Topical Theory Collaborations initiated in FY 2016. A new initiative for Quantum Information Sciences is initiated in the FY19 President's Request.
- **Isotope Program**: Increase R&D investments to enable innovative approaches to produce and process critical isotopes, including R&D on production of alpha-emitters for clinical trials with the potential to revolutionize treatment of metastasized cancers.

Nuclear Physics – Facility Operations

	FY17 Enacted	FY18 Annualized CR Level	FY19 President's Request	FY19 vs. FY17
Medium Energy – TJNAF	99,990	97,868	98,541	-1,449
Heavy Ions – RHIC	174,538	174,372	170,398	-4,140
Low Energy Operations – ATLAS	19,199	19,199	19,199	-
Low Energy Operations – FRIB	-	200	4,000	+4,000
Isotope Program	17,526	18,526	20,975	+3,449
Total	**311,253**	**310,165**	**313,113**	**+1,860**

The FY19 President's Request supports NP's national scientific user facilities (CEBAF, RHIC, ATLAS), initial FRIB operations, the isotope production facilities, and other NP facility commitments.

- **Medium Energy**: The recently upgraded CEBAF is supported for 2,035 hours of scientific operations in FY 2017 (52% of optimal operations), including support for the operations staff, power costs, materials and supplies, and maintenance activities needed as this complex scientific user facility begins to ramp up to full operation mode. The President's Request does not include support for capital equipment, AIP, or GPP.

- **Heavy Ions**: RHIC is operated for 2,795 hours (68% of optimal operations) to optimize data taking and realize RHIC science opportunities in exploring the properties of the quark gluon plasma first discovered there. Support is provided for maintenance, but the President's Request does not include support for capital equipment or AIP.

- **Low Energy**: ATLAS is operated for 5,300 hours (80% of optimal operations) to continue to meet the high demand for this facility, the only operating low energy nuclear science facility in the US, including increased support for mechanical engineering expertise and accelerator target development. The President's Request does not include support for capital equipment at ATLAS. The 88-Inch Cyclotron at LBNL operates for nuclear science research and support of the national security space community, and the ramp-up of FRIB operations continues.

- **Isotope Program**: Support is provided for mission readiness for safe and reliable operations of isotope production and processing facilities at LANL,ORNL and BNL and for operations of the stable isotope enrichment prototype at ORNL.

Nuclear Physics – Projects

Line Items and MIEs (TEC)	FY17 Enacted	FY18 Annualized CR Level	FY19 President's Request	FY19 vs. FY17
Facility for Rare Isotope Beams (FRIB)	100,000	97,200	75,000	-25,000
sPHENIX MIE	-	-	1,200	+1,200
Gamma-Ray Energy Tracking Array (GRETA) MIE	500	500	2,500	+2,000
Stable Isotope Production Facility (SIPF) MIE	2,500	1,500	5,000	+2,500
Total	**103,000**	**99,200**	**83,700**	**-19,300**

FY 2019 funding is requested to initiate the sPHENIX MIE and to continue support for GRETA, SIPF, and FRIB construction.

- **FRIB**: FY 2019 funding supports the ongoing FRIB construction, including the fabrication and assembly of the cryogenics plant and distribution system and the FRIB ion source, as well as the commissioning of the linac system.

  DOE TPC=$635.5M; MSU Cost Share=$94.5M; Total project cost=$730M. Completion (CD-4) by 3Q FY 2022.

- **sPHENIX**: FY 2019 funding supports the initiation of the sPHENIX MIE which will probe the properties of the the QGP medium and their effect on bound quarkonia (the Upsilon states) by comparing p-p, p-A , and A-A collisions. The FY 2019 Request of $1,200,000 supports initial construction activities.

- **GRETA**: The Gamma-Ray Energy Tracking Array (GRETA) MIE, a high resolution gamma array tracking device for FRIB, is continued. The FY 2019 Request of $2,500,000 supports engineering design and long lead procurement.

- **SIPF**: The Stable Isotope Production Facility (SIPF) MIE is continued to provide a cost-effective domestic capability for production of enriched stable isotopes. Many stable isotope supplies are depleted from the national inventory and are needed for important research and security applications. SIPF will help mitigate dependence of the US on foreign suppliers.

Nuclear Physics

FY 2019 President's Request – Summary

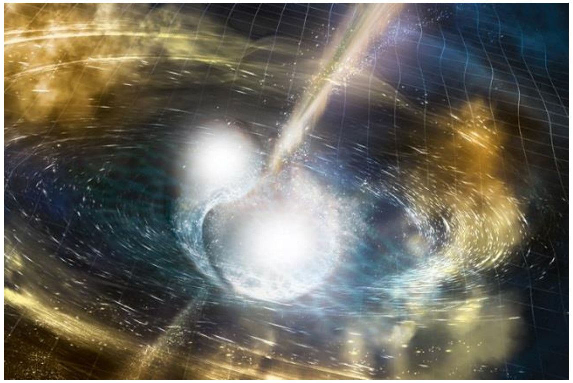
($ in 000s)	FY17 Enacted	FY18 Annualized CR Level	FY19 President's Request	FY19 vs. FY17
Research	182,664	182,807	178,540	-4,124
User Facility Operations	293,727	291,639	292,138	-1,589
Other Operations	21,826	22,826	25,275	+3,449
Projects	103,000	99,200	83,700	-19,300
Other	20,783	21,307	20,347	-436
TOTAL NP	**622,000**	**617,776**	**600,000**	**-22,000**

- **Research** – Support university and laboratory research across the program to address important opportunities identified by the research community, and to enhance high priority research that will foster significant advances in nuclear structure, nuclear astrophysics, the study of matter at extreme conditions, hadronic physics, fundamental properties of the neutron, neutrinoless double beta decay, quantum information sciences and isotope production and processing techniques.
- **User Facility Operations** – Operate the three Nuclear Physics user facilities by supporting staff, equipment, and materials required for reliable operations for research focused on: advancing the understanding of strongly interacting matter and its description in QCD, and to search for evidence of new physics beyond the Standard Model at CEBAF; characterizing the perfect quark-gluon liquid discovered in collisions of relativistic heavy nuclei at RHIC; and advancing the areas of nuclear structure and reactions, low-energy tests of the standard model, and nuclear astrophysics at ATLAS.
- **Other Operations** – Maintain mission readiness of the Isotope Program facilities for the production of radioisotopes and continue operations of the 88-Inch Cyclotron at LBNL.
- **Projects** – Continue FRIB construction according to its baselined profile, continue GRETA and SIPF MIEs, and initiate the sPEHNIX MIE.
- **Other** – Provide required funding for the SBIR/STTR programs consistent with the legislative mandate and WCF to SCPD.

General Outlook

- The FY2019 PR presents some challenges.
- We need to stay focused and continue to deliver important outcomes for the nation.
- Delivering exciting discoveries, important scientific knowledge, technological advances, and workforce training is what we do.
- We need to keep up the good work!

Some Recent Examples



Artist's conception of a binary neutron star merger, which creates a whirling cloud of radioactive debris and a short gamma-ray burst (jets). (Credit: National Science Foundation/LIGO/Sonoma State University/A. Simonnet)

"Origin of the Heavy Elements in Binary Neutron-Star Mergers From a Gravitational-Wave Event

Daniel Kasen[1, 2], Brian Metzger[3], Jennifer Barnes[3], Eliot Quataert[1] […]& Enrico Ramirez-Ruiz

Nature **volume 551**, pages 80–84 (02 November 2017)

Received: 13 September 2017
Accepted: 25 September 2017
Published online: 16 October 2017

The cosmic origin of elements heavier than iron has long been uncertain. Theoretical modelling[1,2,3,4,5,6,7] shows that the matter that is expelled in the violent merger of two neutron stars can assemble into heavy elements such as gold and platinum in a process known as rapid neutron capture (r-process) nucleosynthesis. The radioactive decay of isotopes of the heavy elements is predicted[8,9,10,11,12] to power a distinctive thermal glow (a 'kilonova'). The discovery of an electromagnetic counterpart to the gravitational-wave source[13] GW170817 represents the first opportunity to detect and scrutinize a sample of freshly synthesized r-process elements[14,15,16,17,18]. Here we report models that predict the electromagnetic emission of kilonovae in detail and enable the mass, velocity and composition of ejecta to be derived from observations. We compare the models to the optical and infrared radiation associated with the GW170817 event to argue that the observed source is a kilonova. We infer the presence of two distinct components of ejecta, one composed primarily of light (atomic mass number less than 140) and one of heavy (atomic mass number greater than 140) r-process elements. The ejected mass and a merger rate inferred from GW170817 imply that such mergers are a dominant mode of r-process production in the Universe.

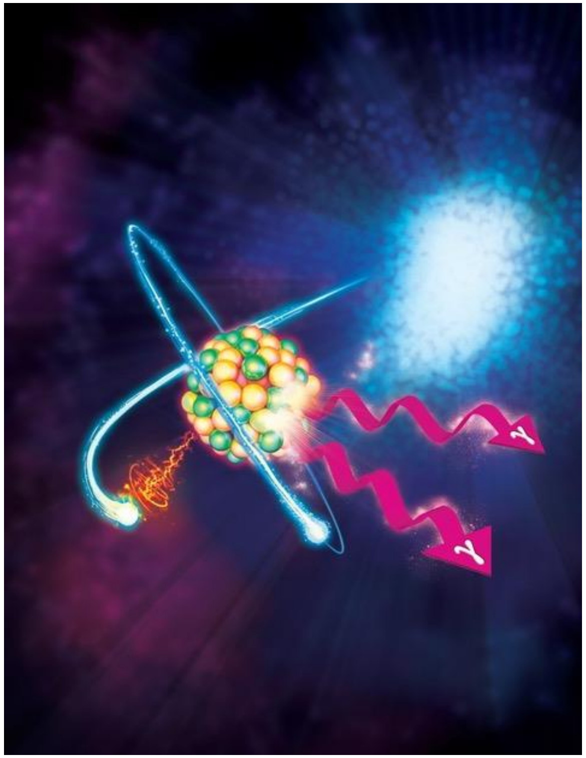
The Largest Rotational Velocity Ever Observed

Global hyperon polarization in nuclear collisions: evidence for the most vortical fluid

Authors: STAR Collaboration
(Submitted on 23 Jan 2017)
Nature 548, 62 (2017)

Abstract: The extreme temperatures and energy densities generated by ultra-relativistic collisions between heavy nuclei produce a state of matter with surprising fluid properties. Non-central collisions have angular momentum on the order of 1000, and the resulting fluid may have a strong vortical structure that must be understood to properly describe the fluid. It is also of particular interest because the restoration of fundamental symmetries of quantum chromodynamics is expected to produce novel physical effects in the presence of strong vorticity. However, no experimental indications of fluid vorticity in heavy ion collisions have so far been found. Here we present the first measurement of an alignment between the angular momentum of a non-central collision and the spin of emitted particles, revealing that the fluid produced in heavy ion collisions is by far the most vortical system ever observed. We find that Λ and Λ-bar hyperons show a positive polarization of the order of a few percent, consistent with some hydrodynamic predictions. A previous measurement that reported a null result at higher collision energies is seen to be consistent with the trend of our new observations, though with larger statistical uncertainties. These data provide the first experimental access to the vortical structure of the "perfect fluid" created in a heavy ion collision. They should prove valuable in the development of hydrodynamic models that quantitatively connect observations to the theory of the Strong Force. Our results extend the recent discovery of hydrodynamic spin alignment to the subatomic realm.

Discovery of Isomer Depletion Via Electron Capture



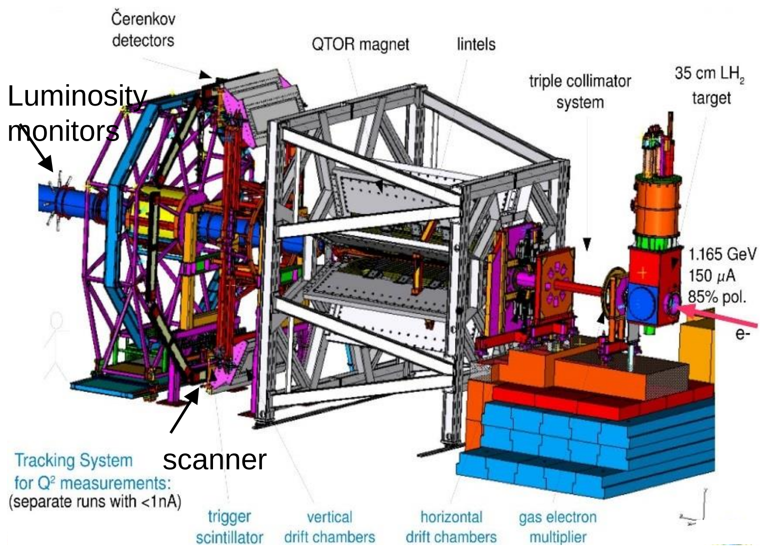
Isomer depletion as experimental evidence of nuclear excitation by electron capture

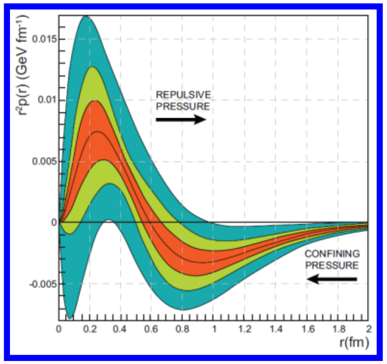
C. J. Chiara[1], J. J. Carroll[2], M. P. Carpenter[3], J. P. Greene[3], D. J. Hartley[4], R. V. F. Janssens[3 n1], G. J. Lane[5], J. C. Marsh[1 n1], D. A. Matters[6], M. Polasik[7], J. Rzadkiewicz[8], D. Seweryniak[3], S. Zhu[3], S. Bottoni[3 n1], A. B. Hayes[10] […] & S. A. Karamian

Nature volume 554, pages 216–218 (08 February 2018)

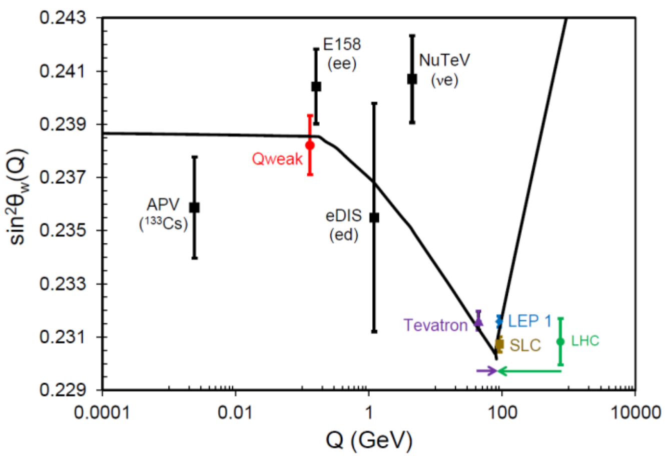
The atomic nucleus and its electrons are often thought of as independent systems that are held together in the atom by their mutual attraction. Their interaction, however, leads to other important effects, such as providing an additional decay mode for excited nuclear states, whereby the nucleus releases energy by ejecting an atomic electron instead of by emitting a γ-ray. This ‘internal conversion’ has been known for about a hundred years and can be used to study nuclei and their interaction with their electrons[1,2,3]. In the inverse process—nuclear excitation by electron capture (NEEC)—a free electron is captured into an atomic vacancy and can excite the nucleus to a higher-energy state, provided that the kinetic energy of the free electron plus the magnitude of its binding energy once captured matches the nuclear energy difference between the two states. NEEC was predicted[4] in 1976 and has not hitherto been observed[5,6]. Here we report evidence of NEEC in molybdenum-93 and determine the probability and cross-section for the process in a beam-based experimental scenario. Our results provide a standard for the assessment of theoretical models relevant to NEEC, which predict cross-sections that span many orders of magnitude. The greatest practical effect of the NEEC process may be on the survival of nuclei in stellar environments[7], in which it could excite isomers (that is, long-lived nuclear states) to shorter-lived states. Such excitations may reduce the abundance of the isotope after its production. This is an example of ‘isomer depletion’, which has been investigated previously through other reactions[8,9,10,11,12], but is used here to obtain evidence for NEEC.

Groundbreaking Insights from JLAB





The pressure distribution inside the proton accepted for publication in *Nature*



Qweak results submitted to *Nature*

State $N(mass)J^P$	PDG pre 2012	PDG 2018*
$N(1710)1/2^+$	***	****
$N(1880)1/2^+$		***
$N(1895)1/2^-$		****
$N(1900)3/2^+$	**	****
$N(1875)3/2^-$		***
$N(2120)3/2^-$		**
$N(2000)5/2^+$	*	**
$N(2060)5/2^-$		**
$\Delta(2200)7/2^-$	*	***

Multiple nucleon resonances now confirmed; highlighted in Particle Data Group (PDG) tables.

New Insights in Fundamental Symmetries

With techniques that use nuclear isotopes inside cryostats, often made of ultra-clean materials, scientists are "tooling up" to study whether neutrinos are their own anti-particle.

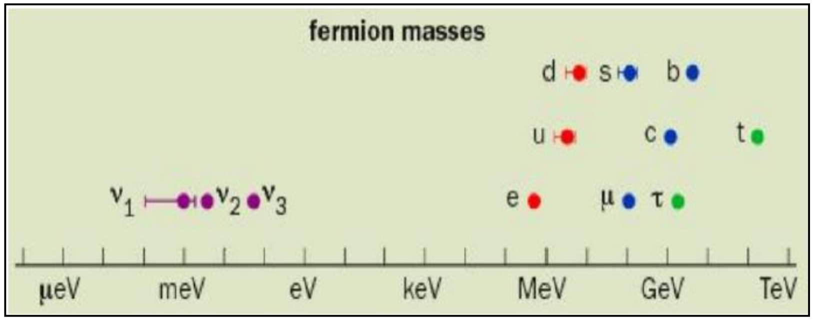
NSAC charged to provide additional guidance on effective strategy for implementing a possible 2nd generation U.S. experiment

Mandrel insertion in MJD electroforming lab

Neutrino-less Double Beta Decay

"Grand Challenge" science questions that will be addressed:

- Is the neutrino its own anti-particle?
- Why is there more matter than anti-matter in the present universe?
- Why are neutrino masses so much smaller than other elementary fermions?



$0\nu\beta\beta$ Demonstrators Pave the Way for a Ton-Scale Experiment

TeO_2 from CUORE and CUOREcino

1.5×10^{25} years, 90% CL

Ge^{76} from Majorana Demonstrator

1.9×10^{25} years, 90% CL

Ge^{76} from GERDA

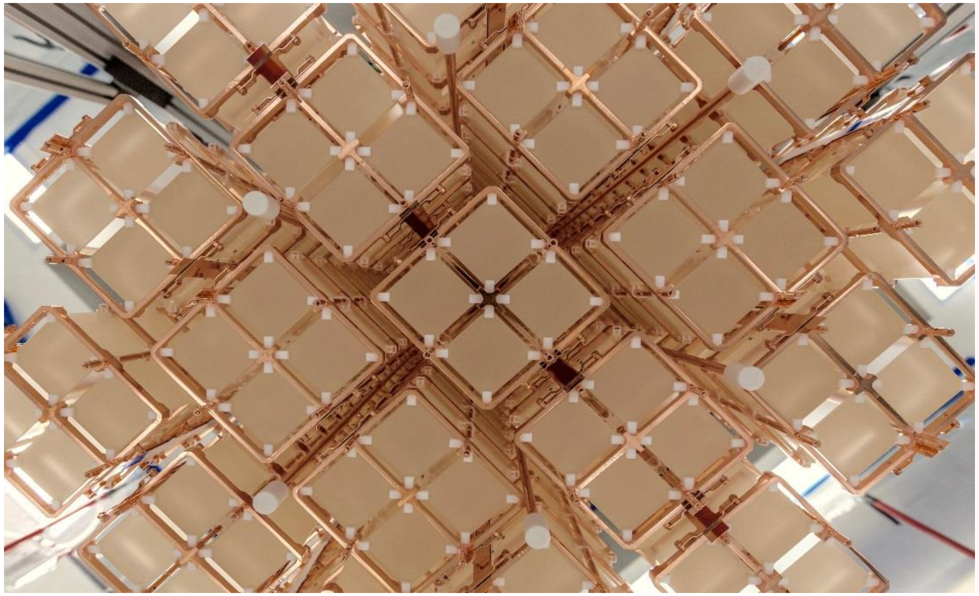
8.0×10^{25} years, 90% CL

Xe^{136} from EXO-200

1.8×10^{25} years, 90% CL

Xe^{136} from Kamland-Zen

1.1×10^{26} years, 90% CL



TeO_2 Crystals from CUORE

NP is working to actively engage international stakeholders

Briefing planned for SC management

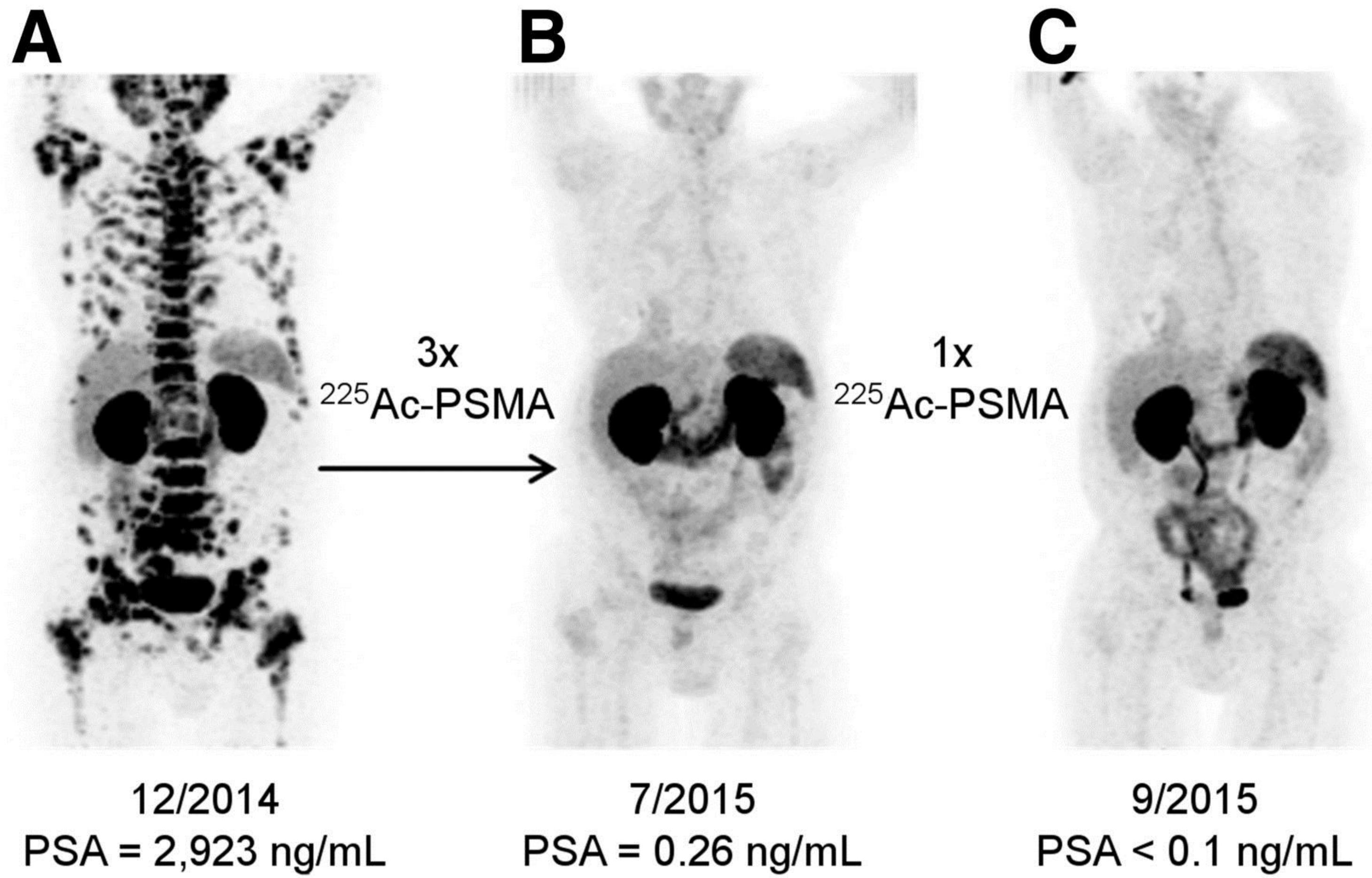
Discussion ongoing of what would constitute CD0 when the time comes

DOE/NSF Coordination of R&D Investments in Neutrino-less Double Beta Decay
February, 2018

Neutrinoless double beta decay (NLDBD) is one of the most compelling and challenging topics in physics and was identified as one of a limited number of recommendations made in the most recent NSAC Long Range Plan for Nuclear Physics (2015). The Office of Nuclear Physics at DOE and the Division of Physics at NSF currently support first generation NLDBD experiments and R & D leading to next generation experiments. The optimal utilization of national resources in support of NLDBD requires coordination between the agencies. The NSAC Subcommittee on Neutrinoless Double Beta Decay (NLDBD) has established the criteria for down selecting the most promising technology approach to the next generation experiments, assessed the critical R & D needs for each candidate technology, and recommended support for R & D aimed at solving specific technical issues relevant to the down selection. Meanwhile, significant technological progress has been made with many demonstrators now operational.

Funding availability now demands that more focused efforts be taken, with priority given to proposals related to technologies that are projected to reach the above referenced down-select criteria in a timely manner and to proposals for staged approaches using current generation technologies that have discovery potential. The agencies intend to move forward and continue their coordinated approach with this perspective.

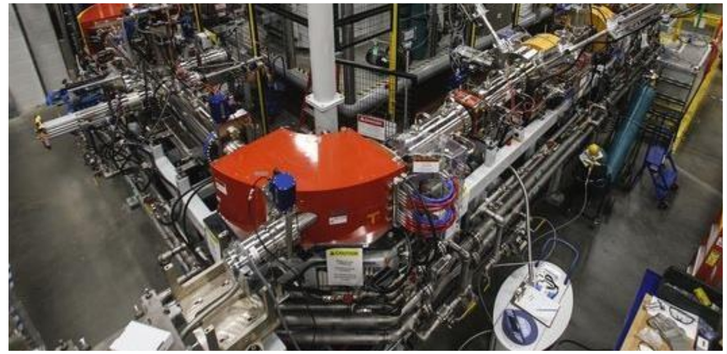
Support for Isotope Research/Mission Readiness to Enable the Saving of Lives



Ga-68 PET/CT scans of a different patient with metastatic prostate cancer. Image **A** shows pre-therapeutic tumor spread. Image **B** was taken 2 months after the third cycle of treatment with the α-emitting isotope Ac-225 attached to a tumor seeking drug. Image **C** was taken 2 months after one additional treatment dose. Clemens Kratochwil et al. J Nucl Med 2016;57:1941-1944

Facility for Rare Isotope Beams is ~ 84% Complete

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 limits of existence for nuclei
- Nuclei that have neutron skins
- Synthesis of super heavy elements

Nuclear Astrophysics

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

Fundamental Symmetries

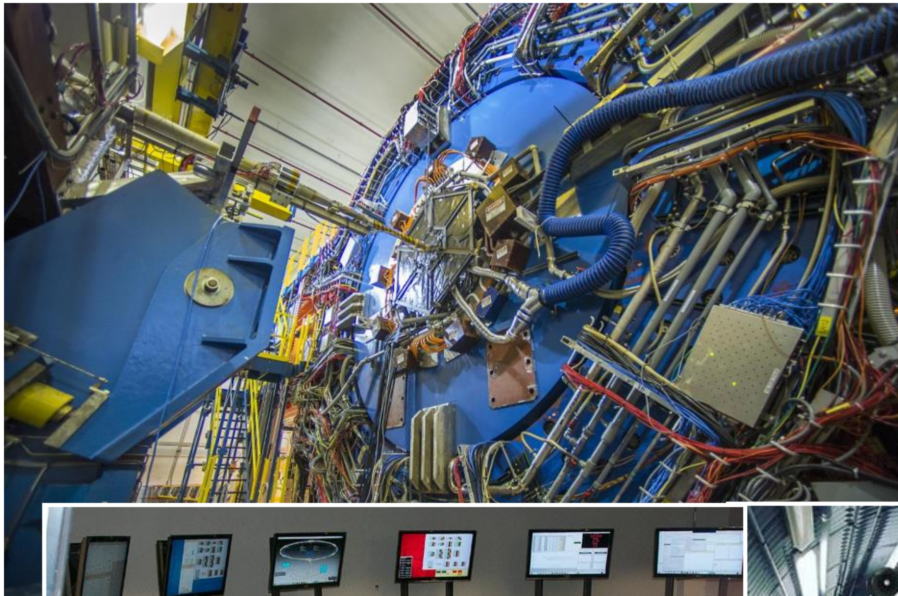
- Tests of fundamental symmetries, Atomic EDMs, Weak Charge

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

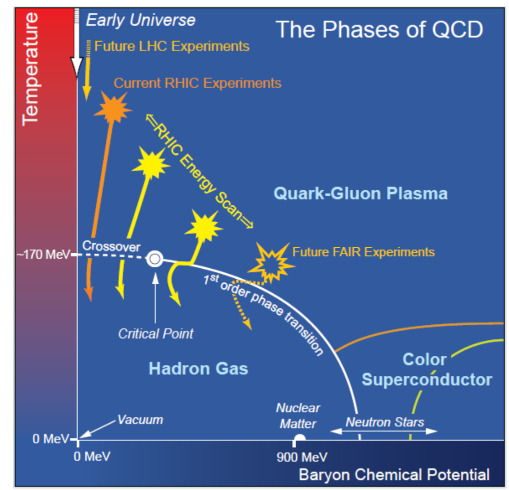
The FY 2019 Request supports:

- The ongoing fabrication, assembly, installation, and testing of cryomodules and experimental systems that will be housed in the newly constructed tunnel.
- The continued commissioning of the linear accelerator (linac) system.
- The continuation of modest pre-operations funding in advance of full scale operations.

RHIC Machine Performance Continues to Set New Records



- In FY 2019, RHIC operates for 19 weeks.
- The FY 2019 Request supports data taking to confirm the explanation of never-before-seen phenomena in quark gluon plasma formation and preparations to search for a critical point between the phases of nuclear matter.
- The FY 2019 Request also supports the construction start of the sPHENIX MIE, which will enable unprecedented observations of the QGP.



- Consistently high facility availability (~85%).
- No other facility worldwide, existing or planned, rivals RHIC in science reach and versatility as a heavy ion collider. It is the only polarized proton collider in the world.

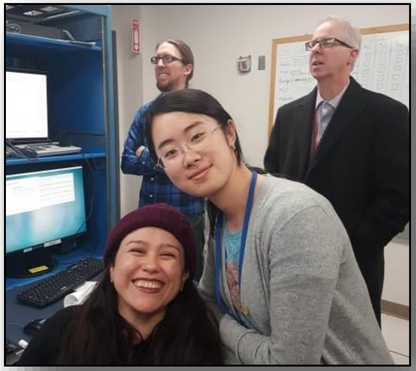
The 12 GeV Science Era has Begun!

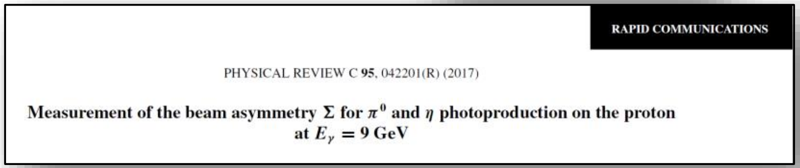
- Hall A: In physics operations
  - First 12 GeV era publications this year
  - December 15, 2017: First Beam on Tritium Target!

- Hall B: In engineering run operations
  - Good progress; Start of CLAS12 Physics early-February
  - Publications anticipated from Proton Radius and Heavy Photon Search experiments

- Hall C: In physics operations
  - New spectrometer engineering run completed; Physics data-taking started January 19!
  - Series of "simple" early measurements will lead to early publications.

- Hall D: In physics operations (GlueX)
  - Engineering Run: Basis for dozens papers at 2016 & 2017 APS Division of Nuclear Physics meetings
  - First 12 GeV era publication: 24 April, 2017! Working on several other publications
  - First physics run (GlueX – search for exotic mesons) begins Spring 2017 and continuing in Spring 2018





RAPID COMMUNICATIONS

PHYSICAL REVIEW C **95**, 042201(R) (2017)

Measurement of the beam asymmetry Σ for π^0 and η photoproduction on the proton at $E_\gamma = 9$ GeV

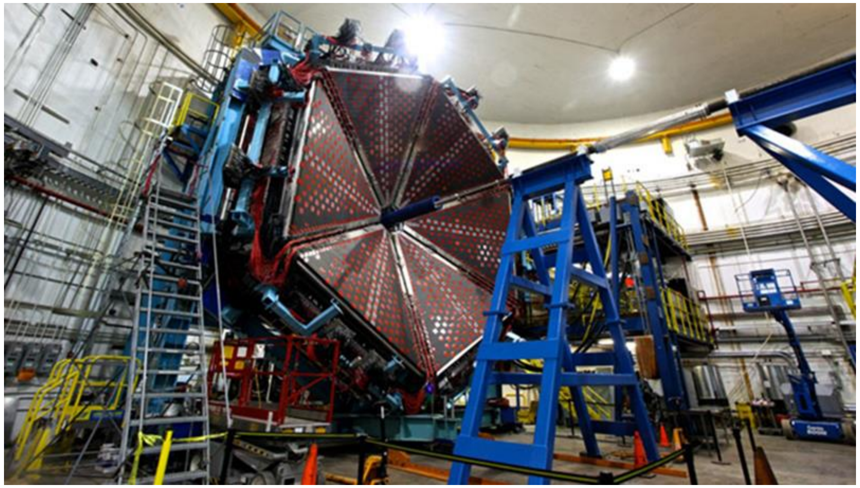
Continuous Electron Beam Accelerator Facility

CEBAF operates for 19 weeks in FY 2019

12 GeV CEBAF Upgrade Science Program is initiated:

- The CEBAF science program continues its science data taking operations following the completion of the 12 GeV Upgrade in FY 2017.
- Concurrent data taking in multiple halls of the four experimental halls, including the recently constructed Hall D, gets underway.

Hall D Solenoidal Spectrometer

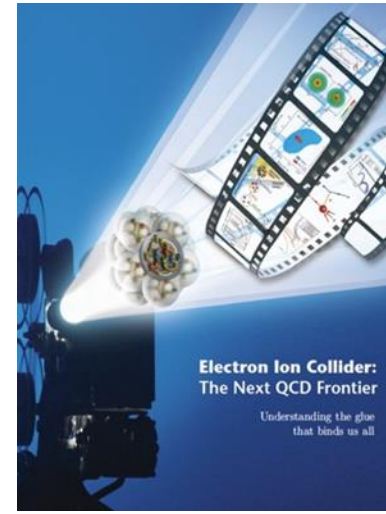


Hall B Time of Flight Detector

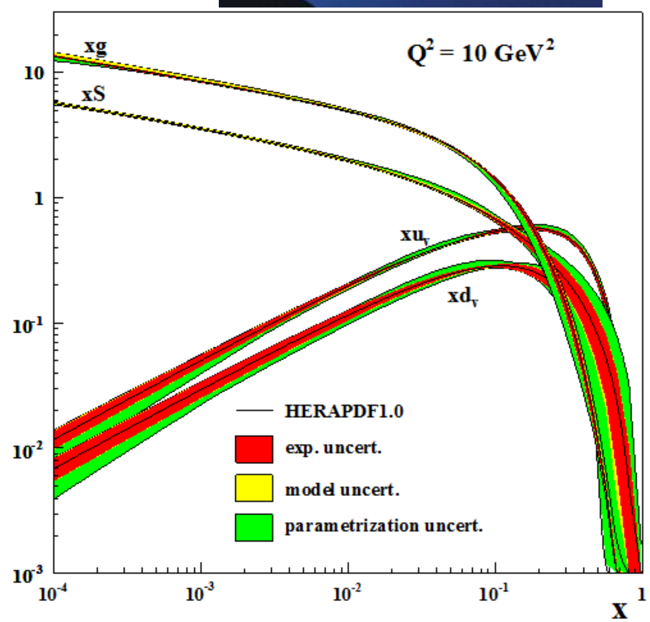
With the completed 12 GeV CEBAF Upgrade, researchers begin experiments to:

- Search for exotic new quark-anti-quark particles to advance our understanding of the strong force.
- Find evidence of new physics from sensitive searches for violations of nature’s fundamental symmetries.
- Gain a 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.

The Longer Term Future of QCD Research: an Electron-Ion Collider



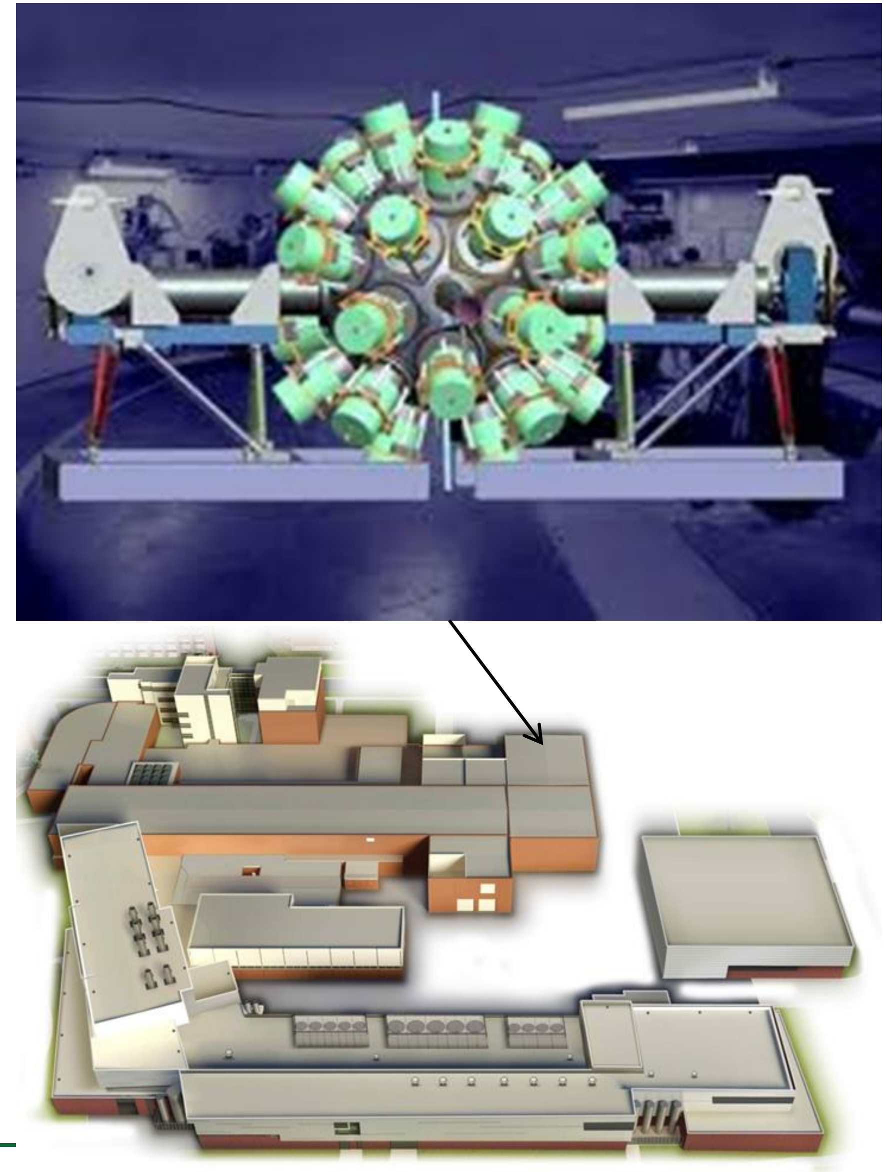
- Proton (and nuclei) and black holes are the only fully relativistic (high enough energy density to excite the vacuum) stable bound systems in the universe. Protons can be studied in the laboratory.
- Protons are fundamental to the visible universe (including us) and their properties are dominated by emergent phenomena of the self-coupling strong force that generates high density gluon fields:
  - The mass of the proton (and the visible universe)
  - The spin of the proton
  - The dynamics of quarks and gluons in nucleons and nuclei
  - The formation of hadrons from quarks and gluons
- The study of the high density gluon field that is at the center of it all requires a high energy, high luminosity, polarized Electron Ion Collider



The 2013 NSAC *Subcommittee on Future Facilities* identified the physics program for an Electron-Ion Collider as ***absolutely central*** to the nuclear science program of the next decade.

Gamma-Ray Energy Tracking Array (GRETA)

- The FY 2019 Request continues the Gamma Ray Energy Tracking Array (GRETA) Major Item of Equipment (MIE) initiated in FY 2017, a premiere gamma-ray tracking device that will exploit the new capabilities of FRIB.
- GRETA was identified by NSAC as an instrument that will "revolutionize gamma-ray spectroscopy and provide sensitivity improvements of several orders of magnitude."
- GRETA will advance the rare-isotope science at FRIB and investigate reactions of importance for nuclear structure and nuclear astrophysics.
- FY 2019 Request: $2.5M
  Est. Total Project Cost: $52M-$67M



Stable Isotope Production Facility (SIPF)

- The FY 2019 Request continues the Stable Isotope Production Facility (SIPF) MIE, which restores domestic capability lacking since 1998:
  - Renewed enrichment capability that will benefit nuclear and physical sciences, industrial manufacturing, homeland security, and medicine.
  - Nurtured U.S. expertise in centrifuge technology and isotope enrichment, useful for a variety of peaceful-use activities.
  - Capability to address U.S. needs for high priority isotopes needed for research, feedstock material for Mo-99 production, and more.
  - Removes U.S. dependence on off-shore suppliers of enriched stable isotopes

Stable Isotope Pilot Production Facility at ORNL

  - Responds to the Persistent Recommendation of the Nuclear Science Advisory Committee for Isotopes (NSACI)
    - 2009 Recommendation: "Construct and operate an electromagnetic isotope separator facility for stable and long-lived radioactive isotopes."
    - 2015 Long Range Plan: "We recommend completion and the establishment of effective, full intensity operations of the stable isotope separation capability at ORNL."

Quantum Information Science and the Office of Science

SC Tools, Equipment, Instrumentation for QIS

Quantum Computing Hardware

ASCR's Testbeds Program:
- Research into device architectures and system integration optimized for science applications
- Development of hybrid platforms and quantum/classical coprocessors
- Early access to new quantum computing hardware for the research community

Tool R&D for QIS

- Extensive nanoscience tools for quantum structure synthesis and integration
- Detectors and metrology
- Quantum sensors enabling precision measurements
- Quantum computational tools
- Superconducting RF cavities, laser cooling, neutral ion traps, spin manipulation technology, and isotope production

Key DOE-SC Contributions:

- Well-established co-design practices in computer hardware development
- History of fundamental research leading to prototype devices, characterization and synthesis tools, and techniques
- Experience in collaborations with industry and core competencies in delivering major projects involving equipment, tools, and instrumentation for discovery and implementation
- Demonstrated success in generating leading scientific tools with and for the international user community

Fundamental Science That Advances QIS

SC will leverage the groundwork already established in DOE National Labs and the academic groups to maximize SC's impact on QIS. Examples include:

In April 2017, the researchers have successfully run the largest ever simulation of a quantum computer at NERSC, LBNL. The simulation was made possible by the performance boost gained through the use of Roofline model during the optimization process. The Roofline model was developed by SciDAC Institutes; a flagship ASCR program.

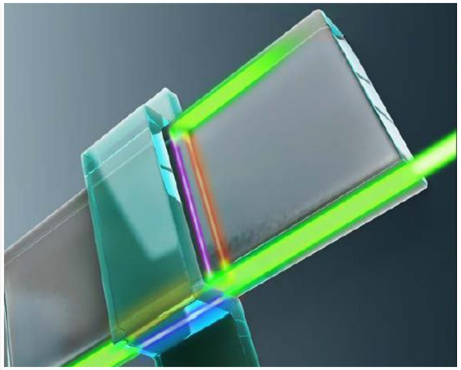
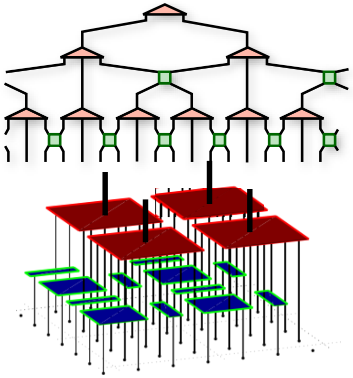
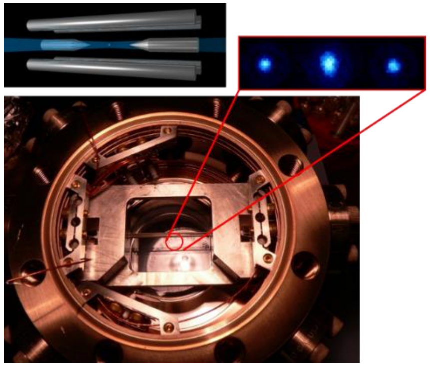


Illustration of a topological insulator with a superconducting layer on top for detection of Majorana fermions (colored lines). Once identified and isolated, Majorana fermions could form the basis of qubits. Electrons (green) travel along the edges of the structure. Supported in part by the BES Energy Frontier Research Center (EFRC) program.



Tensor networks are a key theoretical tool for understanding entanglement, topological order, and other aspects of quantum systems. They comprise a broad family of techniques (2D Multi-scale Entanglement Renormalization Ansatz (MERA) shown here).



A laser cooled, RF confined ion trap at Argonne National Laboratory: trapped ions can be used as qubits and as quantum simulators.

NP-QIS Collaborations - Fundamental Science

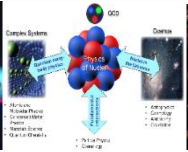
NP-QIS research activities:

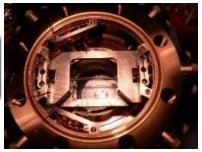
- **NP and Microsoft Research** are in the early stages of collaborating on learning circuits and algorithms, and implementations of time –evolution. Shared interest in Field Theory applications. *The first steps towards a quantum simulator of gauge theories are being taken now.*

- **NP's Institute for Nuclear Theory** studying ground states of many-body systems via Spectral Combing on a Quantum Computer. Spectral Combing requires fewer quantum gates to realize than the Quantum Adiabatic Algorithm. (1-publication).

- **Heterogeneous Digital-Analog Quantum Dynamics Simulations** (**ASCR**). Collaborator: University of Washington, Seattle, (**NP**) exploring Quantum Algorithms.

- **Ion-Trap Quantum Computing.** NP pioneered development of magneto-optical traps and cryogenic polarized nuclear targets. NP is in early stages of exploring chip traps, for ionic or neutral qubits. Miniaturization of atom traps is critical to scalability of this technology. Accelerator R&D applied to RF/Microwave design - a non-trivial component of building a chip traps.





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Where Do Things in NP Stand Now?

Early activities involving nuclear scientists

- INT workshop took place
- Calculation of the binding Energy of the Deuteron
- Workshop at ANL: Intersections between Nuclear Physics and Quantum Information Physics Division, Argonne National Laboratory, 28–30 March 2018

Requested Resources:

- FY18 PR: $45M requested by SC
  - NP may have some resources in FY2018
  - Proposals should be submitted to the open solicitation pursuant to the :Dear Colleague" Letter: …"DOE SC encourages submission of innovative research ideas via <u>any appropriate existing mechanism</u>
- FY19 PR: $105M SC request; $8.3M requested by NP
- NP POC: Gulshan Rai

Institute For Nuclear Theory Report 18-008

QUANTUM COMPUTING FOR THEORETICAL NUCLEAR PHYSICS

A White Paper prepared for the U.S. Department of Energy, Office of Science, Office of Nuclear Physics

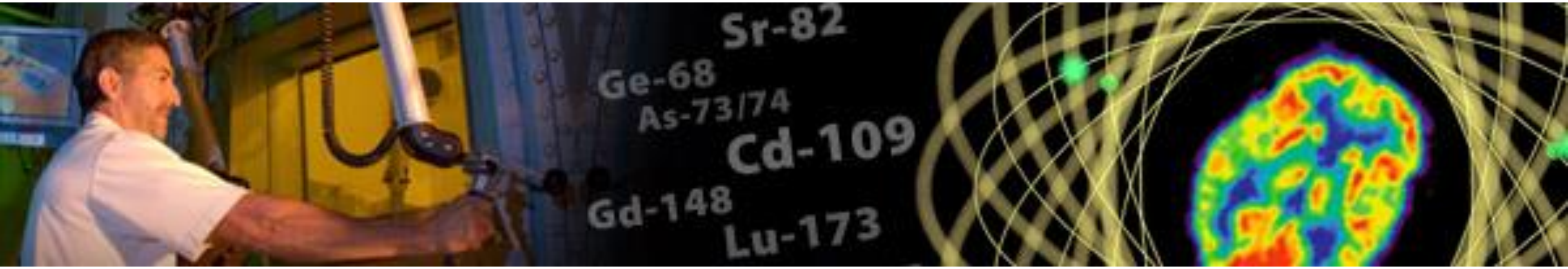
Joseph Carlson (Los Alamos National Laboratory)
David J. Dean (Oak Ridge National Laboratory)
Morten Hjorth-Jensen (Michigan State University)
David Kaplan (Institute for Nuclear Theory)
John Preskill (California Institute of Technology)
Kenneth Roche (Pacific Northwest National Laboratory)
Martin J. Savage (Institute for Nuclear Theory)
Matthias Troyer (Microsoft)

Cloud Quantum Computing of an Atomic Nucleus*

E. F. Dumitrescu,[1] A. J. McCaskey,[2] G. Hagen,[3,4] G. R. Jansen,[5,3] T. D. Morris,[4,3] T. Papenbrock,[4,3,†] R. C. Pooser,[1,4] D. J. Dean,[3] and P. Lougovski[1,‡]

arXiv:1801.03897v1 [quant-ph] 11 Jan 2018

Isotope Program Mission



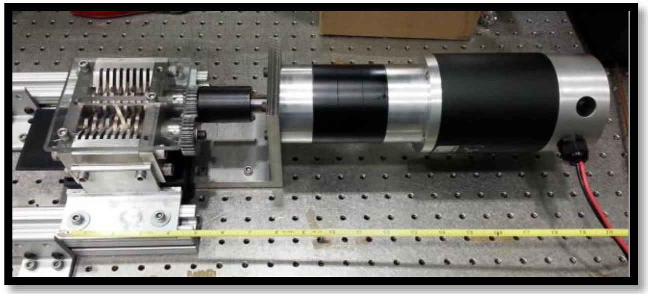
The mission of the DOE Isotope Program is threefold

- Produce and/or distribute radioactive and stable isotopes that are in short supply, associated byproducts, surplus materials and related isotope services.
- Maintain the infrastructure required to produce and supply isotope products and related services.
- Conduct R&D on new and improved isotope production and processing techniques which can make available new isotopes for research and applications.

**Produce isotopes that are in short supply only –
the Isotope Program does not compete with industry**

Ac-227 Production Development

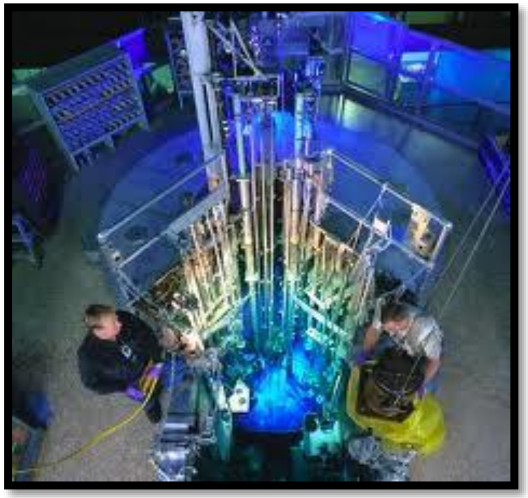
- Bayer drug Xofigo® treats prostate cancer and severe pain from bone metastases; approved in 48 countries.
- Active ingredient Ra-223 from limited global supplies of existing Ac-227.
- Recover Ra-226 from waste medical devices secured by the DOE IP and diverted from a radioactive waste landfill. Ra-226 targets irradiated in HFIR
- Chemically separate and purify the Ac-227 created during irradiation – shipped to Bayer in Norway where they extract Ra-223 which decays into Ac-227and ships it around the world for immediate use as a cancer therapy.
- After 2 years of R&D, scale up to full production in 2017.
- 10-year production contract signed with Bayer end of 2017



The FY2019 Request Supports Further Development of a Regional Network of University Facilities

- Unique capabilities and expertise
- Workforce development
- Cost-effective
- Regional network
- Substantial effort and time:
  - R&D, production capability
  - Contract with DOE
  - Many legal issues
- University of Washington
- University of Missouri - MURR
- University of Wisconsin
- Duke University
- Washington University
- UC Davis

Uni. of Wash cyclotron



University of Missouri Research Reactor

Network Essential for Short-Lived Isotopes

The National Academies of SCIENCES ENGINEERING MEDICINE

THE NATIONAL ACADEMIES PRESS

This PDF is available at http://nap.edu/24993

SHARE

Testing at the Speed of Light: The State of U.S. Electronic Parts Radiation Testing Infrastructure

DETAILS

89 pages | 8.5 x 11 | PAPERBACK

ISBN 978-0-309-47079-7 | DOI 10.17226/24993

NAS Panel Recommendations

Recommendation: The Department of Energy, in collaboration with the Department of Defense and NASA, should establish a joint coordination body to define the usage needs for parts radiation testing and assure the adequacy and viability of radiation test facilities out to 2030. The joint coordination body should be inclusive and recognize the needs of the broader space community.

Recommendation: The joint coordination body or an *equivalently empowered entity* should accomplish the following:

- A review of on testing under way at facilities across the country and internationally;
- An assessment of survey test equipment availability and needs at participating institutions to facilitate sharing and to avoid needless duplication of hardware critical to testing state-of-the-art electronics;
- A strategic forecast of both government and commercial satellite launches that will require radiation-hardened microelectronic and optoelectronic (M&O) components to include reliability and lifetime requirements;
- A joint roadmap developed by representatives from commercial (M&O) device suppliers and the radiation-hardening testing community to ensure test procedures and facilities are capable of testing the latest electronics technologies;

NAS Panel Recommendations

- A facilities plan, updated periodically, which includes the following:

  — A projection of testing time availability of current radiation testing facilities, planned upgrades, and new facilities, including cost-effective strategies for increasing testing capacity and technical support;

  — A review of reliability issues for critical systems at accelerators under current use, which identifies potential threats to sustained operation and the means to mitigate these threats; and

  — An assessment of the business models and financial stability of critical accelerator facilities, which can affect total testing capacity and costs, including the possibility of a dedicated facility for electronics testing; and

- Mechanisms for incentivizing modeling and simulation capabilities, data sharing, and collaborations that can reduce total testing burden.

NAS Panel Recommendations

Recommendation: The Department of Energy (DOE), NASA, the U.S. Air Force, and other interested parties should stabilize funding for proton and heavy-ion accelerator facilities in order to restore resilience in national testing capabilities.

- At the Lawrence Berkeley National Laboratory (LBNL) cyclotron, NASA, DOE, and the Air Force should determine a method to increase beam time availability to the community to meet projected needs and to provide resiliency. The prior joint stewardship program at LBNL was a model for how to exploit this existing U.S. capacity for heavy-ion testing.
- At Texas A&M University, support efforts to bring the K-150 accelerator online for proton and heavy ion-testing.
- Facilitate advanced purchases to guarantee minimum beam time to both the proton and heavy-ion testing community. This will provide greater financial stability to LBNL and proton test facilities in the near term while ensuring access to electronics testers over the coming years. Without such advance purchases, LBNL in particular may need to make staffing and development decisions that harm the interests of the electronics testing community.

Recommendation: The Department of Energy, NASA, and the U.S. Air Force should cooperate with professional organizations (e.g., the Institute of Electrical and Electronics Engineers) and other interested parties to accelerate career development of the younger testing and modeling scientists and engineers through summer schools, short courses, university certificate programs, and internal mentoring to enable them to more rapidly achieve mid-career proficiency levels.

NAS Panel Recommendations

Recommendation: The joint coordination body should assess and support university capabilities for improving space electronics testing and development infrastructure, including the following: the development of advanced accelerator concepts, improved testing strategies, improved radiation hardening solutions designs, and radiation mitigation techniques.

Recommendation: The joint coordinating body should engage with the commercial space sector to ensure testing norms meet the needs of this sector as well as the conventional satellite design and radiation testing communities.

Recommendation: The joint coordination body, in combination with existing working groups, should establish a mechanism to (1) assure the preservation and maintenance of existing modeling and simulation codes for the analysis of space radiation effects on microelectronic and optoelectronic components and (2) support basic research for the development of new codes.

DOE NP News Items

- A second expanded Inter-Agency FOA for nuclear data is being planned for FY18
- The next NP COV will be on or around January, 2019
- Selection process ongoing for FY2018 R&D for Next Generation Nuclear Accelerator Facilities
- Early Career Research Program (Compressed) Process is Underway
- NSAC subpanel on Mo99 has met and is will submit its annual assessment
- FRIB Theory alliance continues to progress and current competitive fellow process nearing completion
- 12 GeV Upgrade completed on cost and on schedule
- Next SCGSR Cohort Selection process underway; deadline is May 15th
- Quadrennial review of lab Low Energy Research will take place August 2018.
- Operations review of the 88 inch cyclotron by NPFPD completed. New IAA in place with AF and soon with NASA as well.
- Report from EIC NAS study expected mid-year

Expectations for Professional Behavior

The Office of Science is exploring the development of an official statement regarding expectations for how individuals it interacts with should conduct themselves.

In the interim, The Office of Nuclear Physics embraces the Code of Conduct adopted by the American Physical Society, and it will remind attendees at meetings it convenes, including review panels, site visits, etc., that it expects a standard for professional behavior that is consistent with the APS declaration.

The APS Code of Conduct

It is the policy of the American Physical Society (APS) that all participants, including attendees, vendors, APS staff, volunteers, and all other stakeholders at APS meetings will conduct themselves in a professional manner that is welcoming to all participants and free from any form of discrimination, harassment, or retaliation. Participants will treat each other with respect and consideration to create a collegial, inclusive, and professional environment at APS Meetings. Creating a supportive environment to enable scientific discourse at APS meetings is the responsibility of all participants.

Participants will avoid any inappropriate actions or statements based on individual characteristics such as age, race, ethnicity, sexual orientation, gender identity, gender expression, marital status, nationality, political affiliation, ability status, educational background, or any other characteristic protected by law. Disruptive or harassing behavior of any kind will not be tolerated. Harassment includes but is not limited to inappropriate or intimidating behavior and language, unwelcome jokes or comments, unwanted touching or attention, offensive images, photography without permission, and stalking.

The Outlook Today

- The U.S. has unquestioned world leadership in experimental QCD research. CEBAF and RHIC are both unique and at the "top of their game" with compelling "must-do" science in progress or about to start. Long term, the future of QCD science is pointing to the need for an electron-ion collider.

- There is a wealth of science opportunity near term at ATLAS, and longer term at FRIB which will be world leading. NP is beginning to position the low energy experimental community to take full advantage of FRIB. The Theory Alliance (and support for theory in general) is also crucial.

- A very high priority for the NP community is U.S. leadership in the science of neutrino-less double beta decay.

  - A specific challenge will be ensuring essential R&D for candidate technologies is completed in the next 2-3 years prior to a down-select for a ton-scale experiment

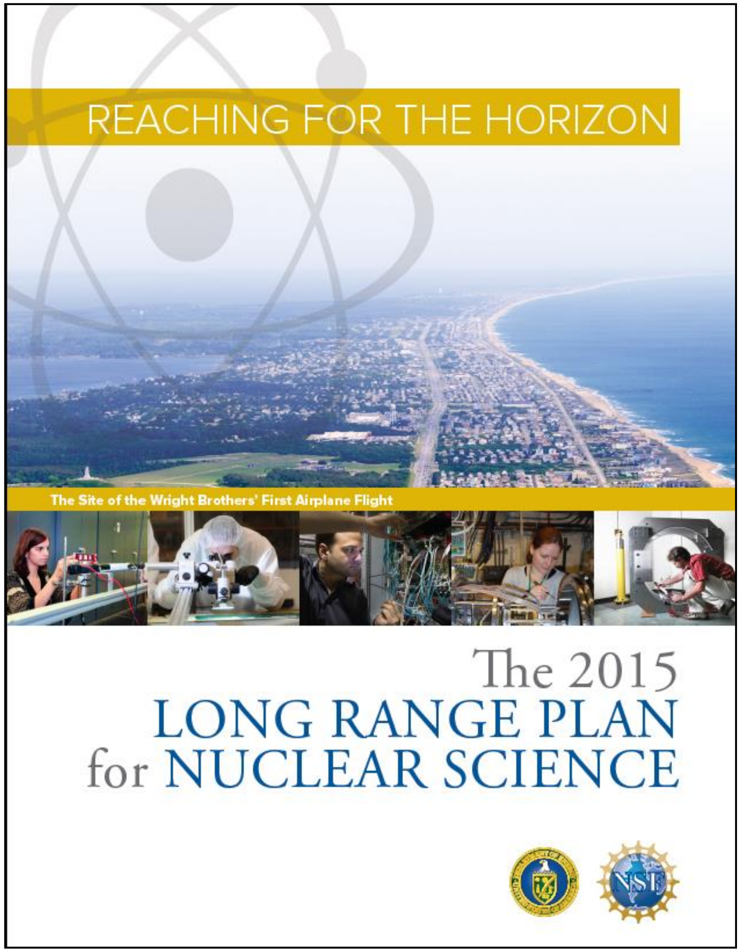
- Research and production efforts to meet the Nation's need for isotopes in short supply are being strengthened; re-establishing U.S. capability for stable isotopes will be a major advance and will help address community concerns in this area documented in the 2009 and 2015 NSACI Strategic Plans

Budget formulation is a process informed by information gathering

The 2015 Long Range Plan for Nuclear Science

Recommendations:

1. Capitalize on investments made to maintain U.S. leadership in nuclear science.
2. Develop and deploy a U.S.-led ton-scale neutrino-less double beta decay experiment.
3. Construct a high-energy high-luminosity polarized electron-ion collider (EIC) as the highest priority for new construction following the completion of FRIB.
4. Increase investment in small-scale and mid-scale projects and initiatives that enable forefront research at universities and laboratories.



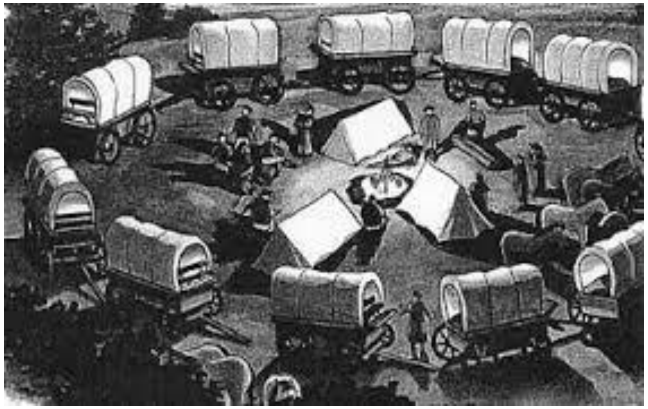
The FY 2019 Request continues to support progress toward the 2015 LRP Vision.

A Long Tradition of Partnership and Stewardship

There has been a long tradition in Nuclear Science of effective partnership between the community and the agencies in charting compelling scientific visions for the future of nuclear science.

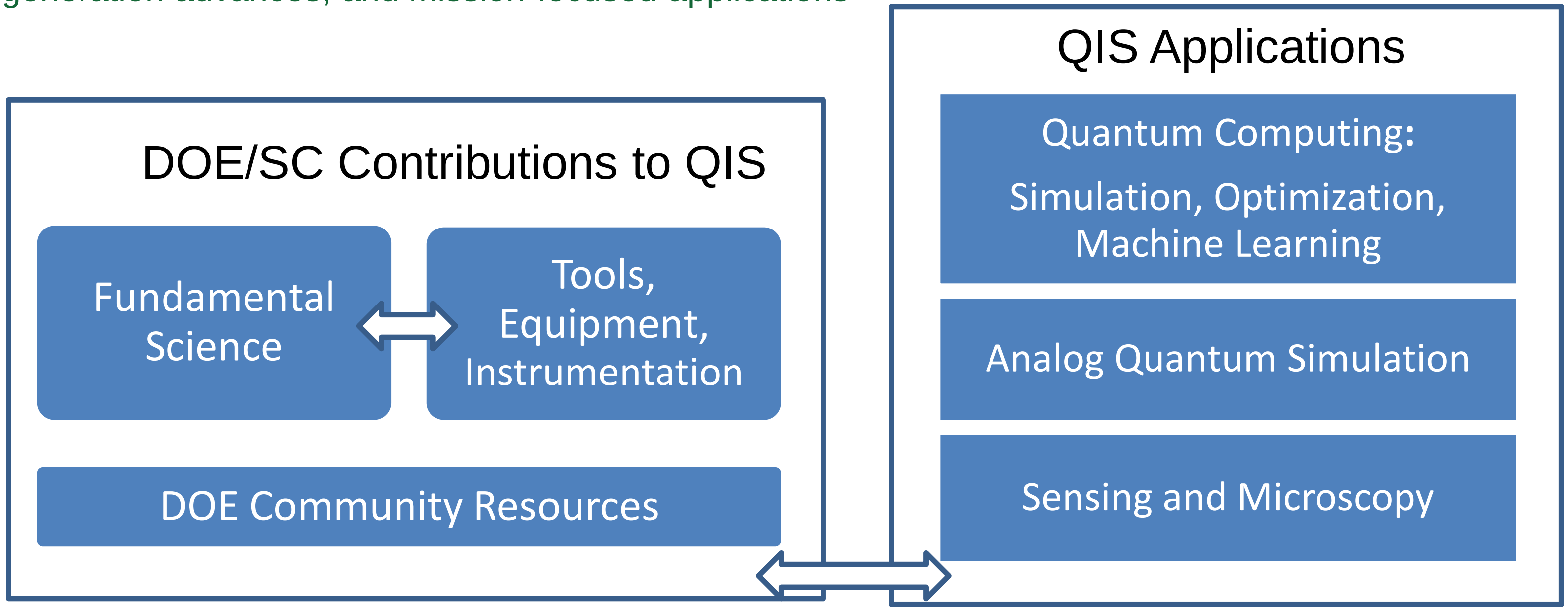
Key factors:

1) Informed scientific knowledge as the basis for recommendations and next steps
2) Mutual respect among scientific sub-disciplines
3) Commitment to the greater good of nuclear science as a discipline
4) Meticulously level playing field leading to respect for process and outcomes
5) Deep appreciation for the wisdom of Ben Franklin



SC's QIS Strategy

- ✓ Builds on community input
- ✓ Highlights DOE/SC's unique strengths
- ✓ Leverages groundwork already established
- ✓ Focuses on cross-cutting themes among programs
- ✓ Targets impactful contributions, science for next-generation advances, and mission-focused applications



Fundamental Science That Advances QIS

ASCR

Quantum algorithms; uncertainty quantification and verification & validation methods; software stack; quantum networks

BES

Synthesis, characterization, theory, modeling, and instrumentation to advance quantum materials & chemical phenomena

HEP

Black hole physics; quantum gravity and quantum error correction; fundamental aspects of entanglement

NP

Isotopes and trapped ions for quantum devices; lattice quantum chromodynamics

Quantum Field Theory and Topology

Control of Quantum Phenomena

SC Unique Strengths

- Intellectual capital accumulated for more than a half-century
- Successful track record of forming interdisciplinary yet focused science teams for large-scale and long-term investments
- Demonstrated leadership in launching internationally-recognized SC-wide collaborative programs

FACA Committees and Regulatory Reform

The Secretary of Energy
Washington, DC 20585

December 07, 2017

MEMORANDUM FOR HEADS OF DEPARTMENTAL ELEMENTS

FROM: RICK PERRY *Rick Perry*

SUBJECT: Federal Advisory Committees and Regulatory Reform

The Department of Energy (DOE) is committed to reducing regulatory burdens on American families and businesses. Earlier this year, DOE formed a Regulatory Reform Task Force to evaluate and reform existing regulations that could eliminate jobs or inhibit job creation that are outdated, unnecessary, ineffective, or imposes costs that exceed benefits. The Task Force's activities are carried out pursuant to the President's direction in Executive Order (EO) 13771, "*Reducing Regulation and Controlling Regulatory Costs*", EO 13777, "*Enforcing the Regulatory Reform Agenda*", and EO 13783, "*Promoting Energy Independence and Economic Growth.*"

FACA Committees and Regulatory Reform

To inform the work of the Task Force, DOE published in the Federal Register a request for information seeking input from the public and those significantly affected by DOE regulations. DOE sought the public's views on specific agency actions that should be altered or eliminated because knowledge about the full effects of rules is widely dispersed in society, and members of the public are likely to have useful information and perspectives on the benefits and burdens of existing requirements and how regulatory obligations may be reformed to achieve regulatory objectives while minimizing regulatory burdens.

DOE understands that its many advisory committees, formed pursuant to the *Federal Advisory Committee Act* (FACA) can also provide valuable input to guide DOE's regulatory reform efforts. DOE's FACA committees are charged with providing advice and recommendations on a wide variety of issues that span the full breadth of work undertaken in support of DOE's mission: to ensure America's security and prosperity by addressing its energy, environmental and nuclear challenges through transformative science and technology solutions.

DOE's FACA committees provide advice on matters related to advanced scientific computing; appliance standards and rulemaking; DOE's Basic Energy Sciences program and biological and environmental research program; biomass research and development (R&D); defense programs; basic nuclear science research; implementing major energy legislation and modernizing the nation's electricity delivery infrastructure; environmental management, specifically accelerated site clean-up, risk reduction, and site-specific

FACA Committees and Regulatory Reform

issues; DOE's fusion energy sciences program; experimental and theoretical high energy physics; hydrogen research, development and demonstration activities; potential applications of methane hydrates and recommendations for methane hydrates R&D;

policy matters relating to coal, matters relating to oil and natural gas, and the oil and gas industries; DOE's nuclear energy program; DOE's basic and applied R&D activities, economic and national security policy, and educational and operational issues; and the initiation, design, implementation, and evaluation of federal energy efficiency and renewable energy programs.

Given the significant amount of expertise possessed by DOE's FACA committees and their members, and the President's direction to reduce regulatory burdens, I hereby direct each FACA committee, in carrying out the charges for which they were created, to consider regulatory reform and to provide appropriate advice and recommendations on DOE regulations, guidance or policies. I am particularly interested in suggestions concerning how DOE regulations, guidance or policies can be improved, streamlined or eliminated.

To ensure that DOE's regulatory reform efforts continue to move forward expeditiously, committees should begin consideration of such reform recommendations immediately, and I hereby direct that each committee place regulatory reform on the agenda for the next meeting of the committee. Designated Federal Officers should respond to Daniel Simmons, DOE's delegated head of the Regulatory Reform Task Force, with topics discussed and any recommendations for reform provided by their respective committees.

Interest in QIS Research is Increasing Rapidly

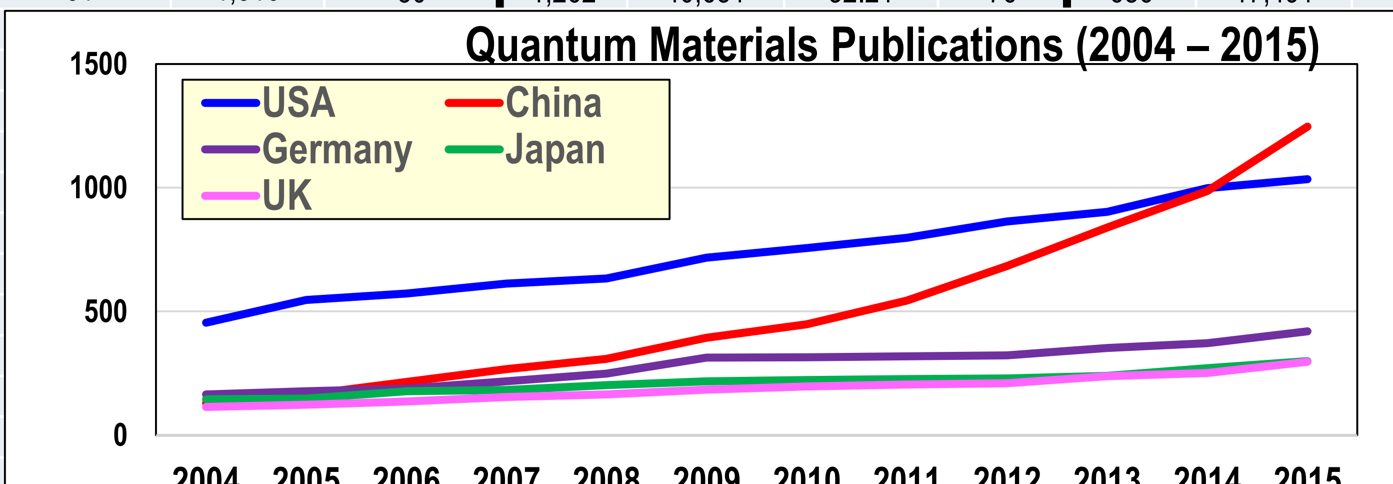
Quantum Materials & Quantum Chemistry: Web of Science Stats (2004 – 2015)

				Quantum Materials				Quantum Chemistry			
Country	Population (M)	GDP ($B)	GDP/PC ($K)	# papers	Total Citations	Avg. Citations	h-index	# papers	Total Citations	Avg. Citations	h-index
USA	322	18,036	56	8,887	435,947	49.05	266	4,459	173,140	38.06	163
China	1,373	11,182	8.1	6,225	157,889	25.36	155	2,709	48,366	17.85	90
Germany	82	3,365	41	3,406	107,079	31.44	135	2,029	72,044	35.51	100
Japan	127	4,124	32	2,559	72,391	28.29	115	851	17,397	20.44	57
UK	65	2,858	44	2,259	114,171	50.54	113	904	42,342	46.84	79
France	64	2,420	38	1,867	60,317	32.31	92	1,192	40,733	34.17	75
India	1,292	2,073	1.6	1,614	25,417	15.75	64	710	10,471	14.75	40
South Korea	51	1,378	27	1,515	42,562	28.09	81	255	9,625	37.75	41
Italy	61	1,816	30	1,262	40,651	32.21	76	686	17,491	25.5	59
Canada	36	1,551	43	1,083	40,544	37.44	91	564	18,492	32.79	58
Russia	143	1,326	9.2	1,065	23,203	21.79	52	859	17,795	20.72	37
Spain	46	1,200	26	966	39,069	40.44	76	752	18,154	24.14	58
Taiwan	23	523	22	885	19,300	21.81	67	167	3,888	23.28	30
Switzerland	8.2	664	80	663	37,880	57.13	82	395	16,267	41.18	56
Australia	24	1,225	51	636	19,033	29.93	63	331	9,790	29.58	43
Poland	38	475	12	604	7,411	12.27	37	442	7,207	16.31	36
Netherlands	17	751	44	533	34,427	64.59	84	256	19,734	77.09	47
Sweden	9.8	493	50	528	13,996	26.51	57	322	13,021	40.44	50
Brazil	204	1,773	8.7	486	7,177	14.77	42	265	3,738	14.11	27
Singapore	5.5	293	53	469	18,654	39.77	65	86	4,920	57.21	25
Belgium	11	454	41	346	9,427	27.25	46	282	6,236	22.11	41

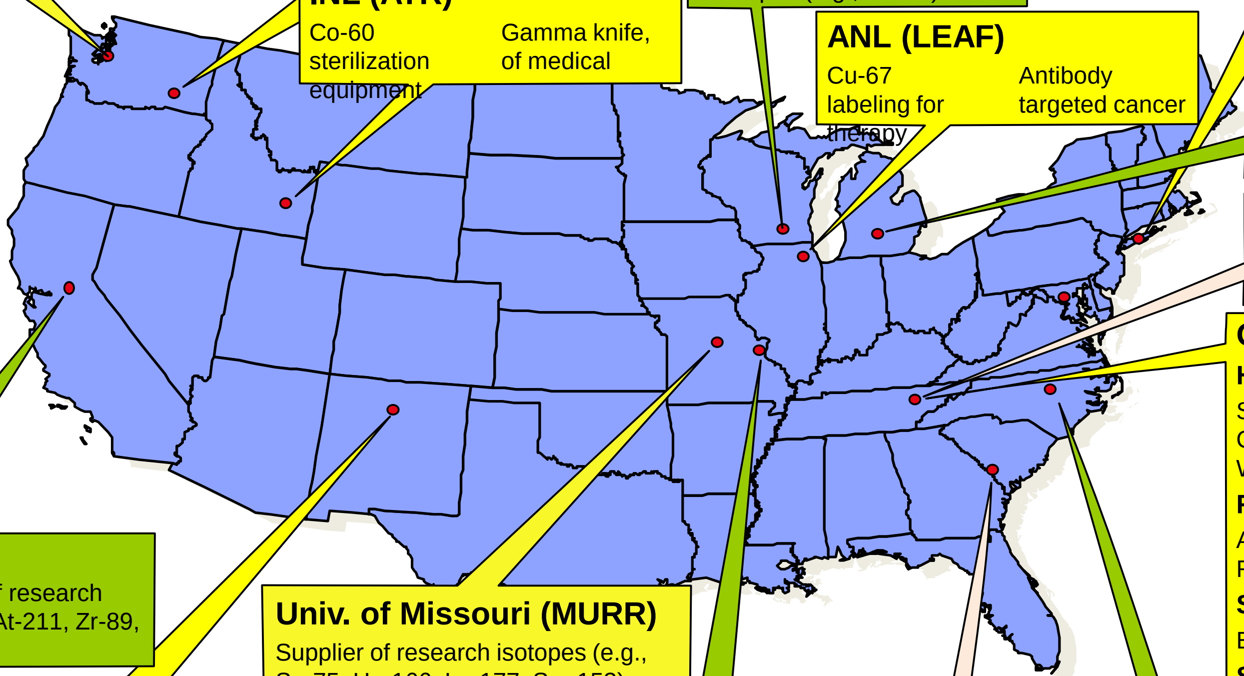
Interest in QIS Research is Increasing Rapidly

Quantum Materials & Quantum Chemistry: Web of Science Stats (2004 – 2015)

				Quantum Materials				Quantum Chemistry			
Country	Population (M)	GDP ($B)	GDP/PC ($K)	# papers	Total Citations	Avg. Citations	h-index	# papers	Total Citations	Avg. Citations	h-index
USA	322	18,036	56	8,887	435,947	49.05	266	4,459	173,140	38.06	163
China	1,373	11,182	8.1	6,225	157,889	25.36	155	2,709	48,366	17.85	90
Germany	82	3,365	41	3,406	107,079	31.44	135	2,029	72,044	35.51	100
Japan	127	4,124	32	2,559	72,391	28.29	115	851	17,397	20.44	57
UK	65	2,858	44	2,259	114,171	50.54	113	904	42,342	46.84	79
France	64	2,420	38	1,867	60,317	32.31	92	1,192	40,733	34.17	75
India	1,292	2,073	1.6	1,614	25,417	15.75	64	710	10,471	14.75	40
South Korea	51	1,378	27	1,515	42,562	28.09	81	255	9,625	37.75	41
Italy	61	1,816	30	1,262	40,651	32.21	76	686	17,491	25.5	59
Canada										2.79	58
Russia										0.72	37
Spain										4.14	58
Taiwan										3.28	30
Switzerland										1.18	56
Australia										9.58	43
Poland										6.31	36
Netherlands										7.09	47
Sweden										0.44	50
Brazil										4.11	27
Singapore										7.21	25
Belgium										2.11	41



DOE Isotope Program Production and/or Development Sites -2018



Univ. of Washington
Supplier of research isotopes (e.g., At-211)

PNNL
Sr-90 therapy — Y-90 generator for cancer
Ra-223 — Cancer therapy
Np-237

INL (ATR)
Co-60 sterilization equipment — Gamma knife, of medical

Univ. of Wisconsin
Development of research isotopes (e.g., Cu-64)

ANL (LEAF)
Cu-67 labeling for therapy — Antibody targeted cancer

BNL (BLIP)
Ge-68 — Ga-68 generator for tumor imaging
Sr-82 — Rb-82 generator for cardiac imaging
Cu-67 — Antibody labeling for targeted cancer therapy

Michigan State Univ.
FRIB isotope harvesting development

Y-12 (NNSA Facility)
Li-6 — Neutron detection
Li-7 — Radiation dosimeters

ORNL

HFIR:

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

Radioisotopes Inventory:

Ac-225	Cancer therapy
Ra-223	Cancer therapy

Stable Isotopes Inventory:
E.g., Ca-48, Ga-69, Rb-87, Cl-37

Stable Isotope Production

UC Davis
Development of research isotopes (e.g., At-211, Zr-89, Y-86, Pb-203)

Univ. of Missouri (MURR)
Supplier of research isotopes (e.g., Se-75, Ho-166, Lu-177, Sm-153)

LANL (IPF)

Ge-68	Ga-68 generator for tumor imaging
Sr-82	Rb-82 generator for cardiac imaging
As-73	Environmental tracer
Si-32	Oceanographic research

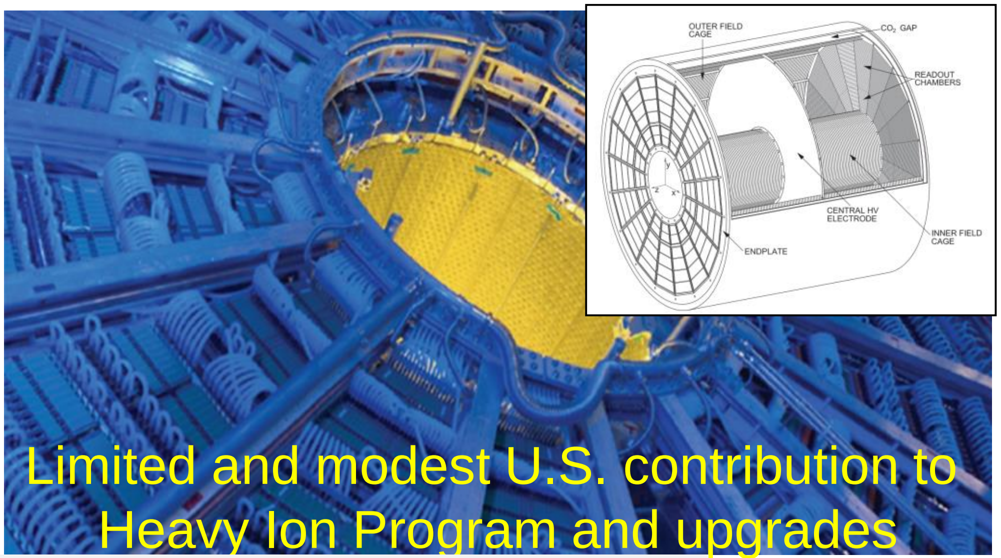
Washington Univ.
Development of research isotopes (e.g., Cu-64)

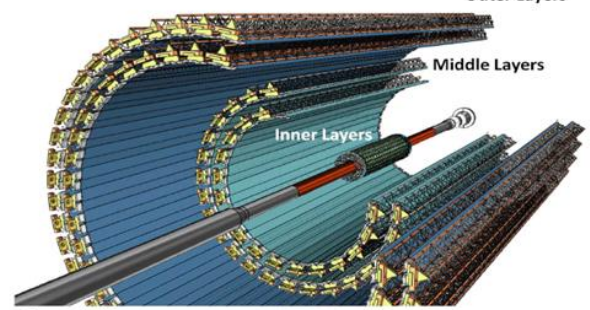
Duke University
Development of research isotopes (e.g., At-211)

SRNL (NNSA Tritium Facility)
He-3 — Neutron detection
Fuel source for fusion reactors
Lung testing

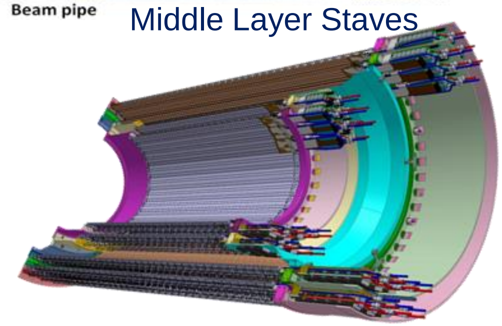
ALICE-USA – Targeted Investments

Continue modest participation in heavy ion program at the LHC – complimentary to RHIC program; provide scientific leadership and small equipment contributions (university led) to ALICE, CMS, and ATLAS





Middle Layer Staves

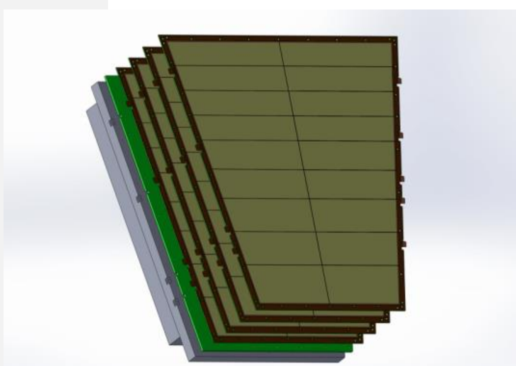


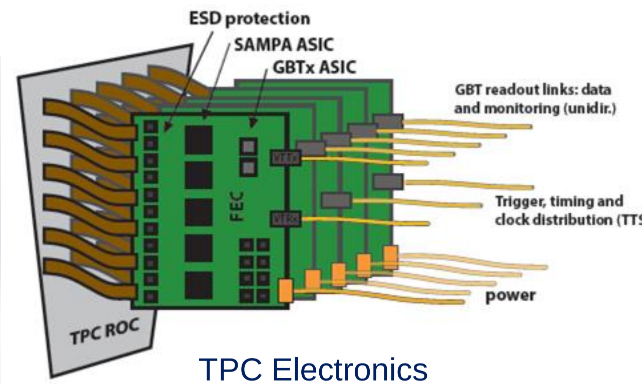
Composite Material Support Structure

U.S. contribution to ALICE:

Time Projection Chamber (TPC):
- Inner Readout Chambers
- Readout Electronics

Silicon Inner Tracker System (ITS)
- Middle layer detector staves
- Electronics readout system
- Carbon Fiber support structure



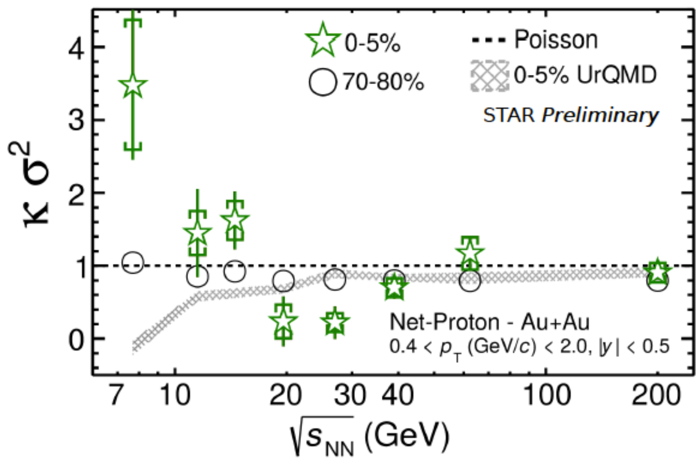


TPC Electronics

Statistics (Beam Time) is a Challenge for the Beam Energy Scan

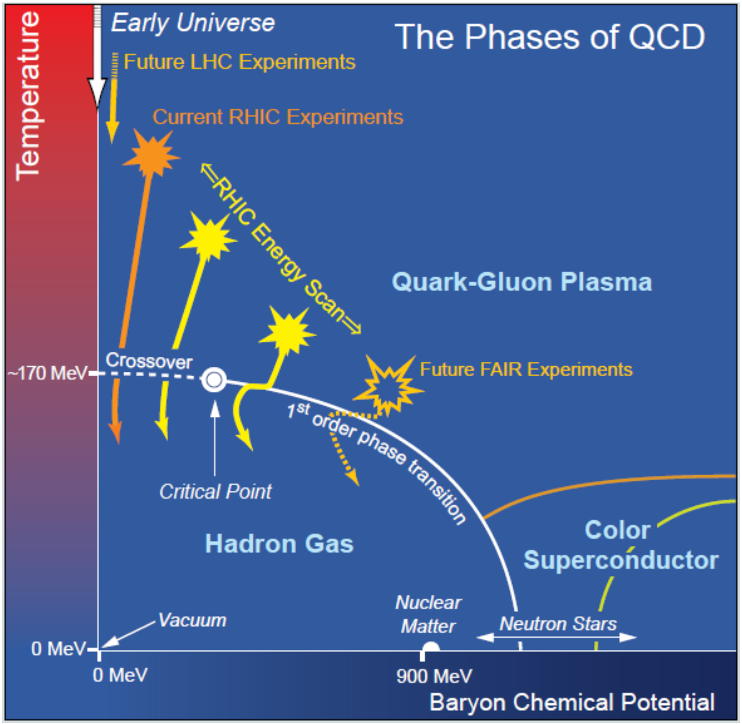
One striking fact is that the liquid-vapor curve can end. Beyond this "Critical Point" the sharp distinction between liquid and vapor is lost. The location of the Critical Point and of the phase boundaries represent two of the most fundamental characteristics for any substance.

Experimentally verifying the location of fundamental QCD "landmarks" is central to a quantitative understanding of the nuclear matter phase diagram..



A primary signature of the Critical Point will be non-Poissonian scaled kurtosis (net baryon number fluctuations)

Results from the first survey run appear tantalizing, but the statistics do not allow a conclusion. Fluctuations consistent with Poissonian behavior fall along the line at unity



~ 10 weeks available for a search planned for a 2 year campaign (~ 48 weeks)