Perspectives from DOE NP

US LHC Users Meeting

November 4, 2016

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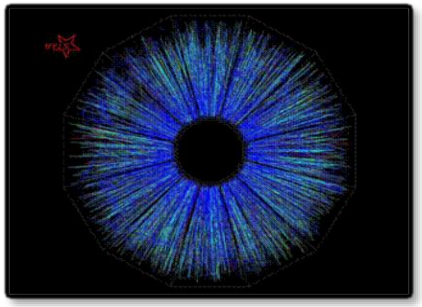
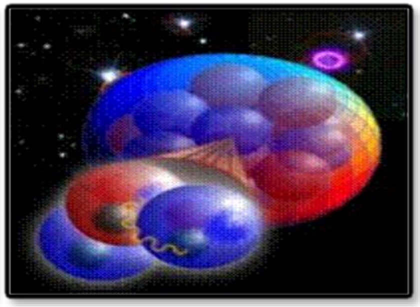
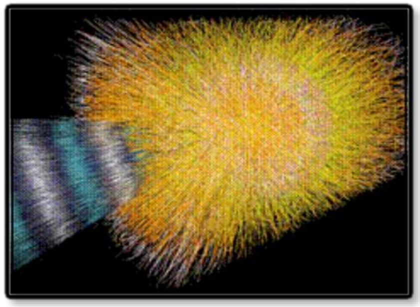
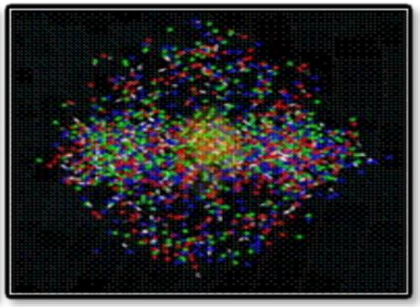
DOE Office of Science

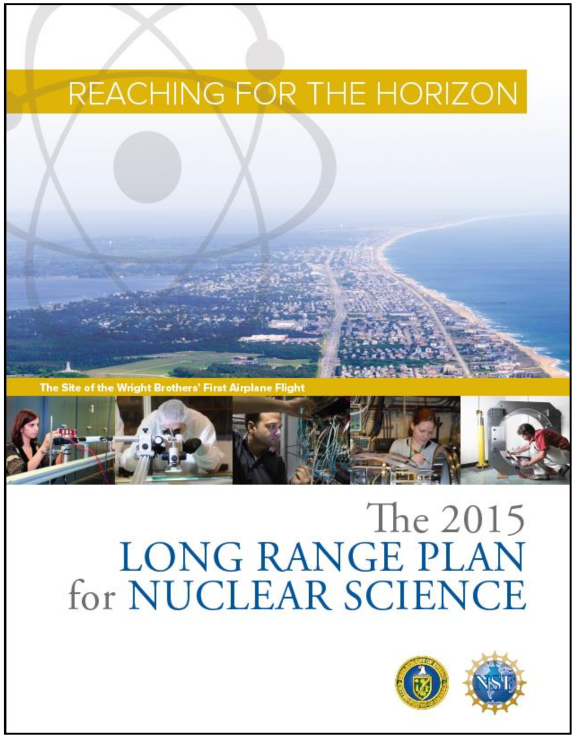





The 2015 Long Range Plan for Nuclear Science

NSAC and APS DNP partnered to tap the full intellectual capital of the U.S. nuclear science community in identifying exciting, compelling, science opportunities

Recommendations:

- The progress achieved under the guidance of the 2007 Long Range Plan has reinforced U.S. world leadership in nuclear science. ***The highest priority in this 2015 Plan is to capitalize on the investments made.***
- The observation of neutrinoless double beta decay in nuclei would…have profound implications.. ***We recommend the timely development and deployment of a U.S.-led ton-scale neutrinoless double beta decay experiment.***
- Gluons…generate nearly all of the visible mass in the universe. Despite their importance, fundamental questions remain…. These can only be answered with a powerful new electron ion collider (EIC). ***We recommend a high-energy high-luminosity polarized EIC as the highest priority for new facility construction following the completion of FRIB.***
- ***We recommend increasing investment in small-scale and mid-scale projects and initiatives that enable forefront research at universities and laboratories.***



NP is implementing these recommendations which are supported in the President's FY 2017 request

Next Formal Step on the EIC Science Case

THE NATIONAL ACADEMIES OF SCIENCES, ENGINEERING, AND MEDICINE
Division on Engineering and Physical Science
Board on Physics and Astronomy
U.S.-Based Electron Ion Collider Science Assessment

Summary
The National Academies of Sciences, Engineering, and Medicine ("National Academies") will form a committee to carry out a thorough, independent assessment of the scientific justification for a U.S. domestic electron ion collider facility. In preparing its report, the committee will address the role that such a facility would play in the future of nuclear science, considering the field broadly, but placing emphasis on its potential scientific impact on quantum chromodynamics. The need for such an accelerator will be addressed in the context of international efforts in this area. Support for the 18-month project in the amount of $540,000 is requested from the Department of Energy.

"U.S.-Based Electron Ion Collider Science Assessment" is now getting underway. The Chair will be Gordon Baym. The rest of the committee, including a co-chair, will be appointed in the next couple of weeks. The first meeting is being planned for January, 2017

Community Review of EIC R&D Status and Needs, Kevin Jones, Chair

Kevin Jones, Chair (ORNL), Oliver Bruning (CERN), John Corlett (LBNL), George W. Dodson (ORNL), Oliver Kester (TRIUMF), John Lewellen (LANL), Daniela Leitner (MSU), Sergei Nagaitsev (FNAL), Alexander Romanenko (FNAL), John Seeman (SLAC), John P. Tapia (LANL), Jie Wei (MSU), Ying Wu (Duke), Frank Zimmermann (CERN)

The Review is scheduled for Nov 29-Dec 2 at the Hilton Washington DC/Rockville, Rockville, MD.

It will center around EIC design concepts: JLEIC Concept, Linac-Ring eRHIC Concept, Ring-Ring eRHIC Concept

As appropriate, Laboratories and Universities have been asked by the Chair to submit documents describing:

- their concept(s)
- a prioritized R&D list for the proposed concept
- related technical and planning documents.

<u>Charge Elements</u>

<u>Status of EIC R&D to date</u>:	Evaluate current state of EIC-related accelerator R&D supported to date.
<u>EIC design concepts:</u>	Examine the current EIC design concepts under consideration and identify a risk level (High, Medium or Low) for each.
<u>Technical feasibility:</u>	Identify key areas of accelerator technologies that must be demonstrated or advanced significantly in order to realize the technical feasibility of each concept;
<u>Priority list of R&D:</u>	Generate a list of R&D areas for each EIC design concept, prioritized (High, Medium, Low) in the context of associated risk and impact of activity to value engineering and technical feasibility. Identify R&D items that have relevance to multiple EIC design concepts; and
<u>Cost and schedule range:</u>	To the extent possible and within the time constraints of the meeting, provide an estimate of cost and schedule range for each item on the R&D list above.

DOE NP News Items

- COV recommendations and NP responses posted at:

http://science.energy.gov/~/media/sc-2/pdf/cov-np/2016/NP_COV_2016_Response.pdf

  - Seeking approval to re-open slot for Research Division Director
  - Gail Dodge has agreed to head a committee to identify candidates for NP DD search
  - FS and LE PM positions will be re-advertised October 26, 2016
  - IPA identified to manage HI program beginning in spring of 2017
  - Planning underway to enhance competitive peer review of renewal proposals
  - NP is proactively attempting to increase diversity on committees and panels

- Planned revision of the peer review process for renewals: up to two awards handled within the current approach via mail reviews; third proposed award included in competitive peer review with all new proposals from the annual "campaign" for that year.

- Paul Sorensen has joined NP as an IPA to manage the Fundamental Symmetries Portfolio

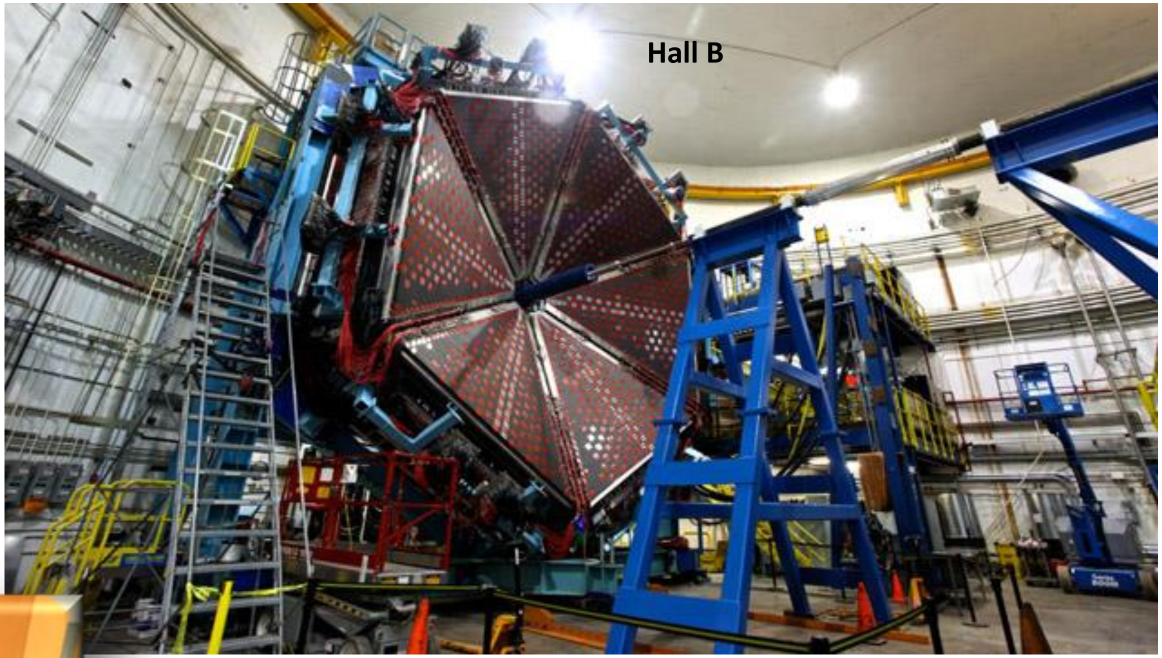
- Chris Gould has joined NP as an IPA to manage the Low Energy Portfolio

- $0\nu\beta\beta$ R&D FOA released August 29,2016; close date October 28, 2016 (http://science.energy.gov/np/funding-opportunities/)

- Joint DOE-AF-NASA NAS study on infrastructure needed for space radiation effects testing is getting underway: "*Space Radiation Effects Testing Infrastructure for the U.S. Space Program".* Committee constituted in 4-6 weeks, First meeting planned for February, 2016.

The 12 GeV CEBAF Upgrade at TJNAF is ~ 98.4 % Complete

Project completion (CD-4B) is planned by the end of FY 2017



With the completion of the 12 GeV CEBAF Upgrade, researchers will address:

- 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.

Facility for Rare Isotope Beams is Approaching 70% 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 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.

	PYs	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	DOE Total	MSU	TOTAL
FUNDING PROFILE	318,000	100,000	97,200	75,000	40,000	5,300	635,500	94,500	730,000

FRIB Construction Continuing to Advance Quickly

On Friday, October 14, 2016, the first FRIB ion beam was produced from the Artemis electron-cyclotron-resonance (ECR) ion source. About 300 euA of oxygen 3+ beam was extracted from the ion source and struck the Faraday Cup downstream (Figure 1).

The ECR ion source is installed on the newly constructed high voltage platform in the FRIB building. Supporting utilities in the FRIB building were made available before the Beneficial Occupancy Date of March 2017.

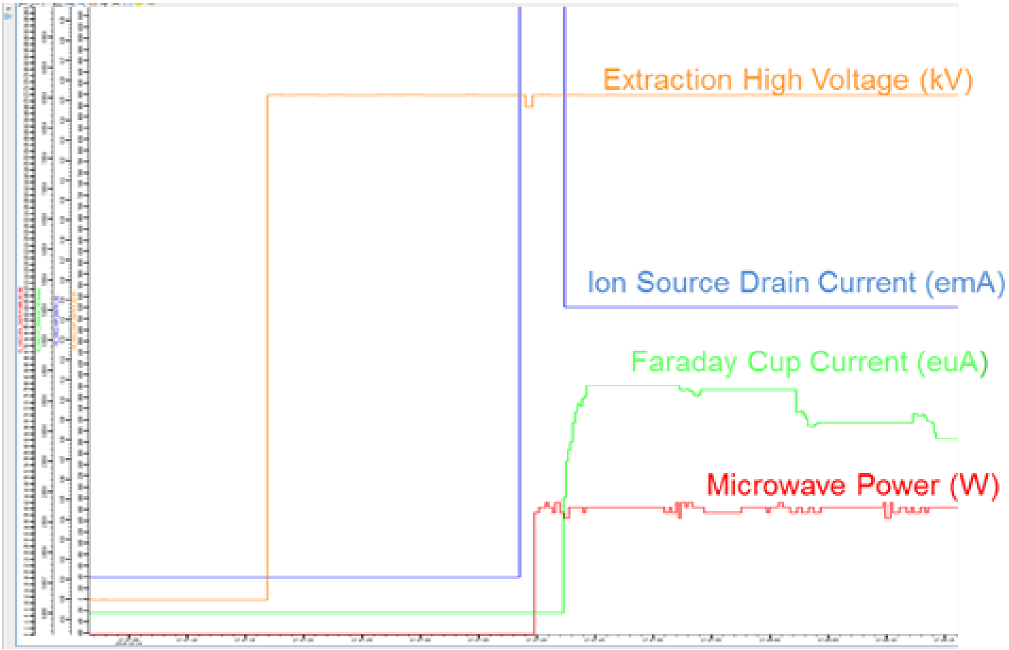
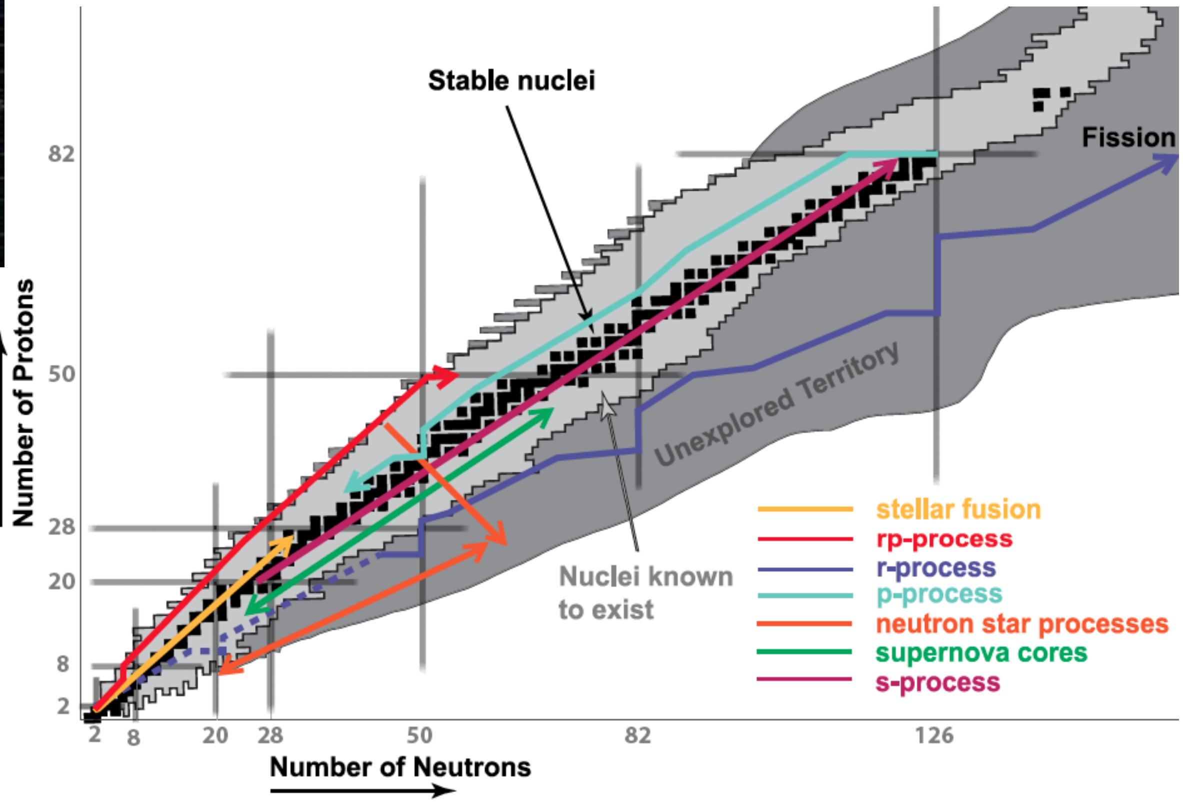


Figure 1: ion source drain current and current on the Faraday Cup downstream of the ARTEMIS ion source when the microwave power is turned on to triggered the ECR plasma and when the extraction voltage is applied. Congratulations to the ion source team members, who made the beam, and to the whole FRIB team, which advanced the baseline schedule through close collaboration between technical and civil construction divisions.

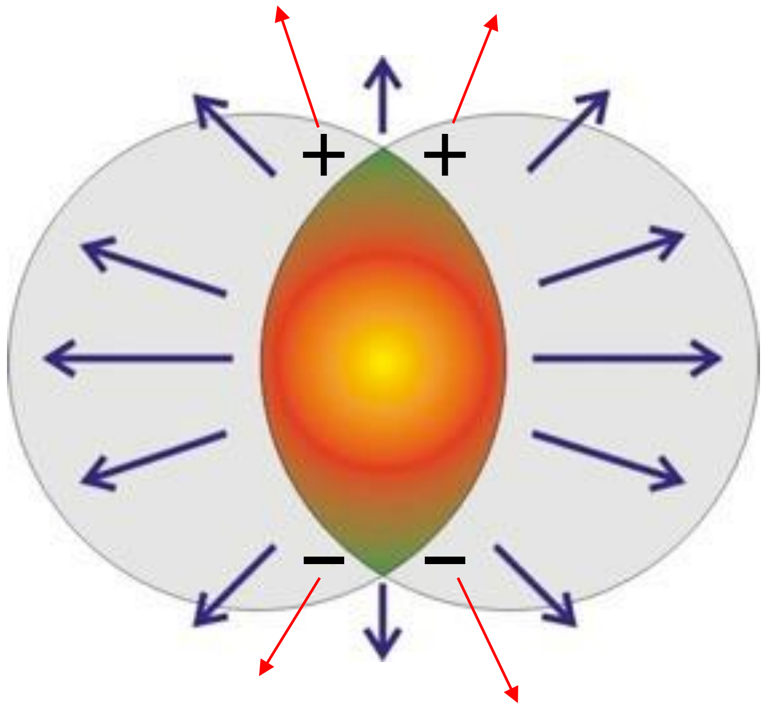
FRIB Promises a Watershed in Understanding Astrophysical Scenarios

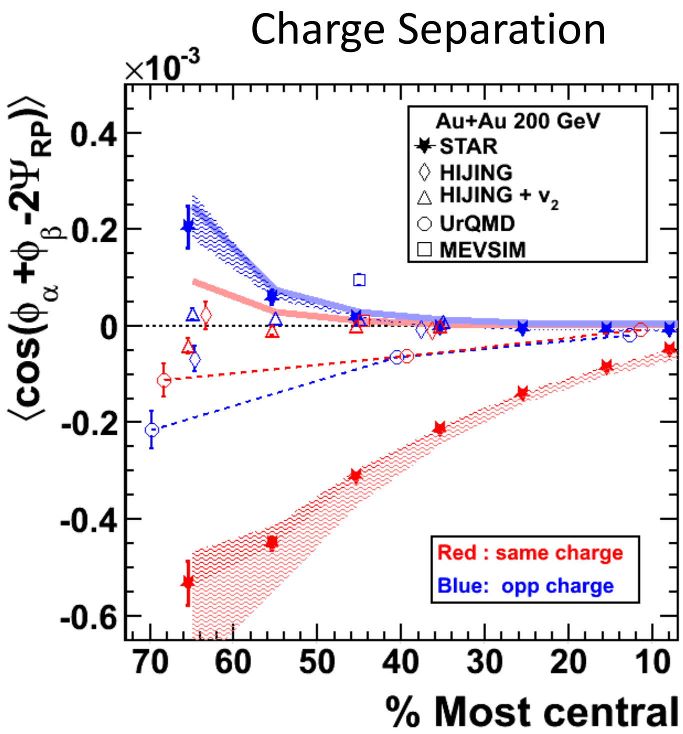
FRIB capabilities will illuminate the rates for many nuclear reactions currently inaccessible, particularly for nuclei with an excess of neutrons

Possible New Paradigm for Production of Heavier Elements: Neutron STAR Mergers



RHIC Poised for a Breakthrough ion Understanding a Very Striking Phenomena





Other experimental observables studied,

- Beam energy dependence
- System size dependence

All observables studied to date are consistent with the interpretation the effect provides a direct window into the nature of the QCD vacuum

Final test: vary the magnetic field using isobars ^{96}Ru and ^{96} Zr

A 20% effect expected if the "Chiral Magnetic Effect" Interpretation is confirmed

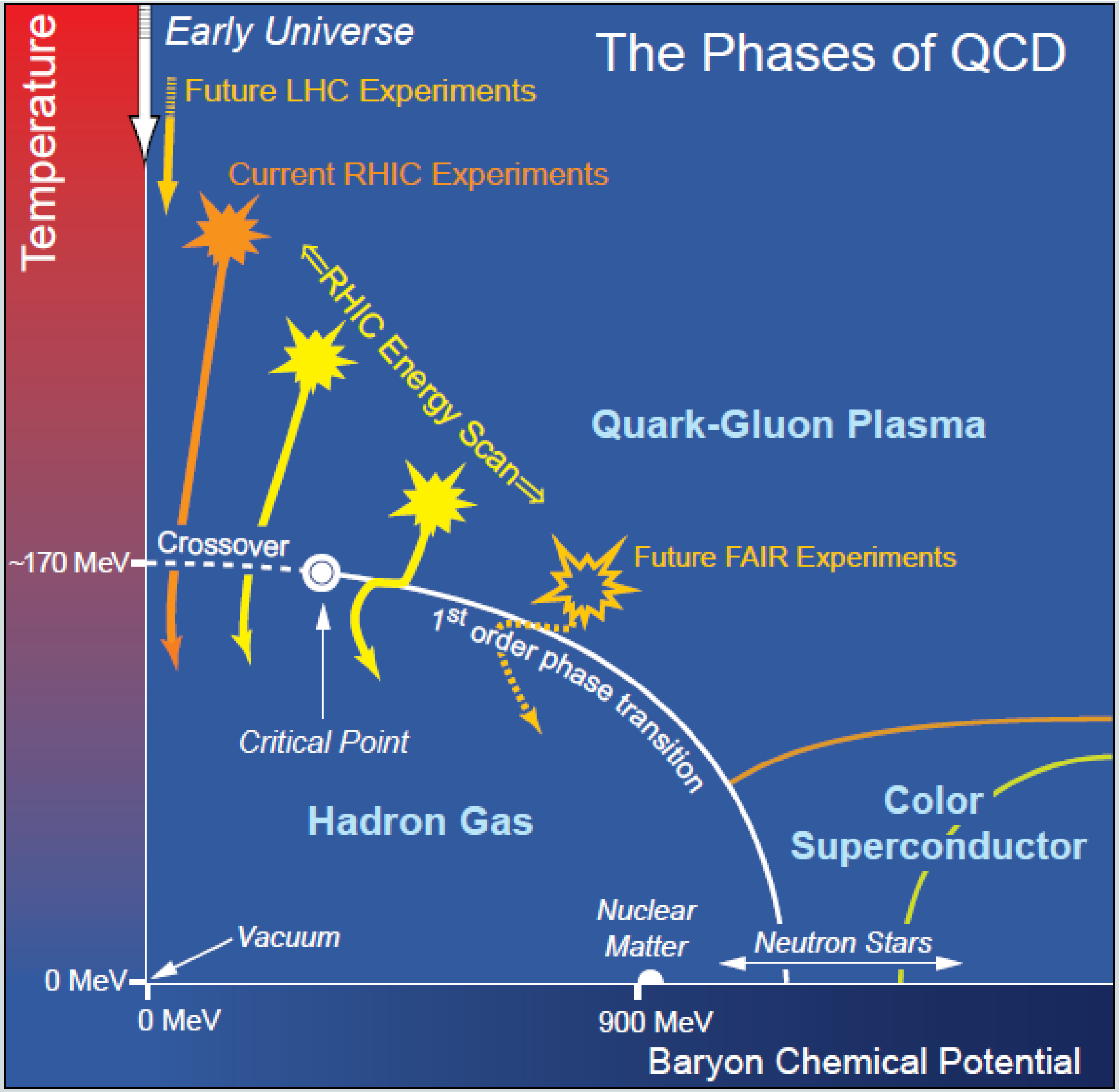
The QCD Critical Point Search: A Main Focus of RHIC Running in FY19-20

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.

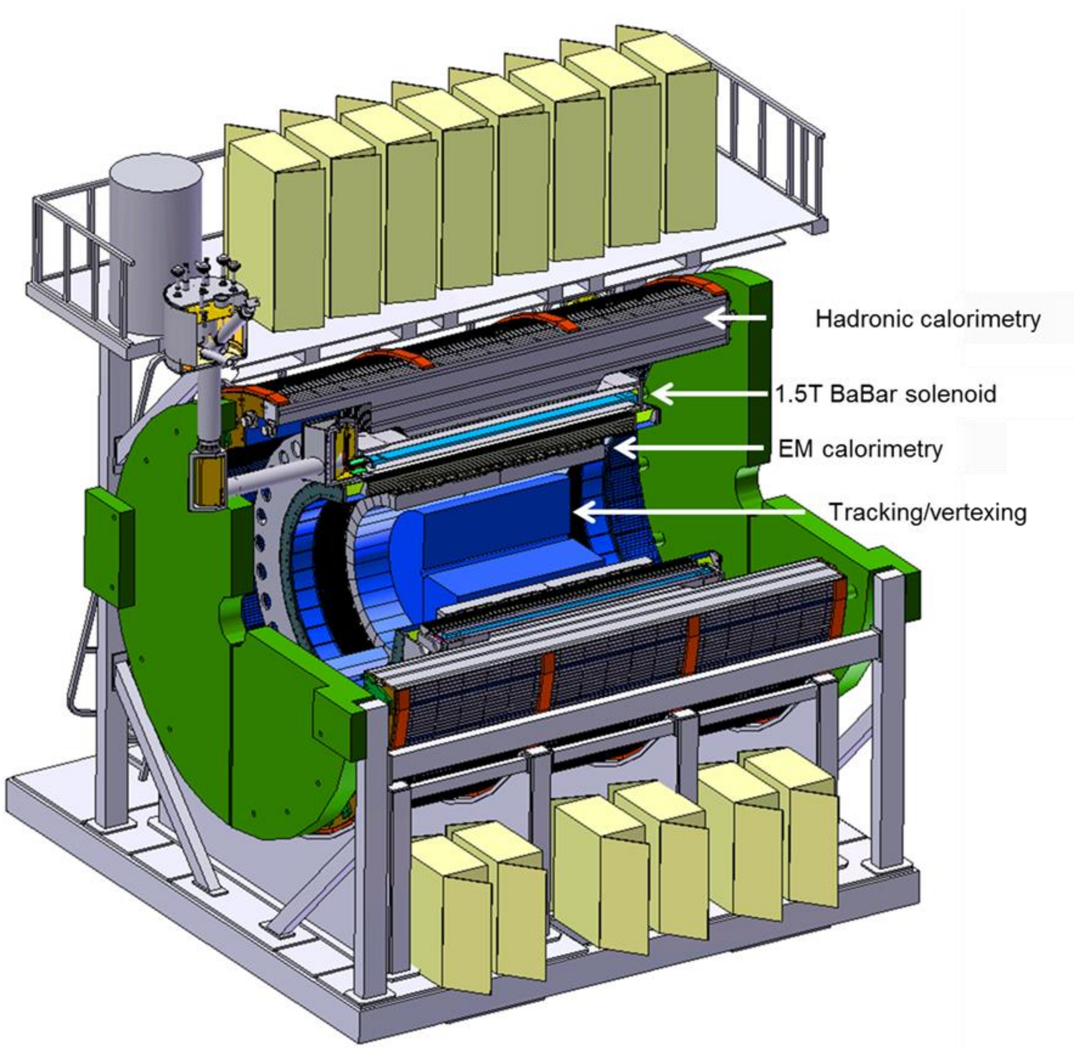
Experimentally verifying the location of fundamental QCD “landmarks” is central to a quantitative understanding of the nuclear matter phase diagram. Lattice QCD indicates that the Critical Point is in the range of temperatures and chemical potentials accessible with RHIC. The approach to the Critical Point will be signaled by large-scale fluctuations in key observables.

Status:

- BES I data are very intriguing
- Further high statistics data require e-cooling (LEReC) implemented in FY18
- BES II planned for FY19-20



The Physics Thrusts of sPHENIX

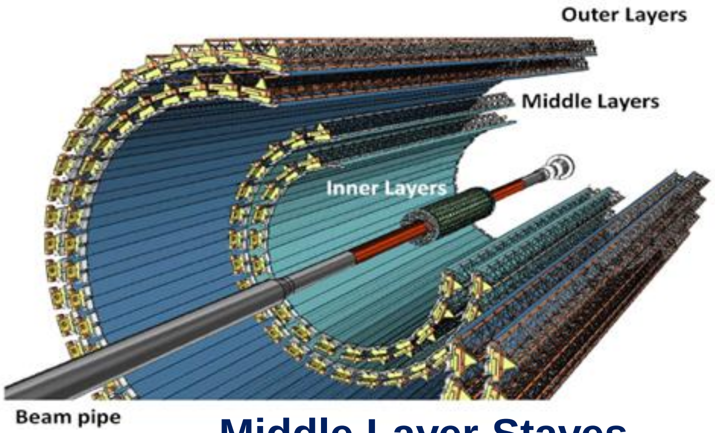


CD-0 approved for sPHENIX on September 27, 2016

The main scientific thrusts are:

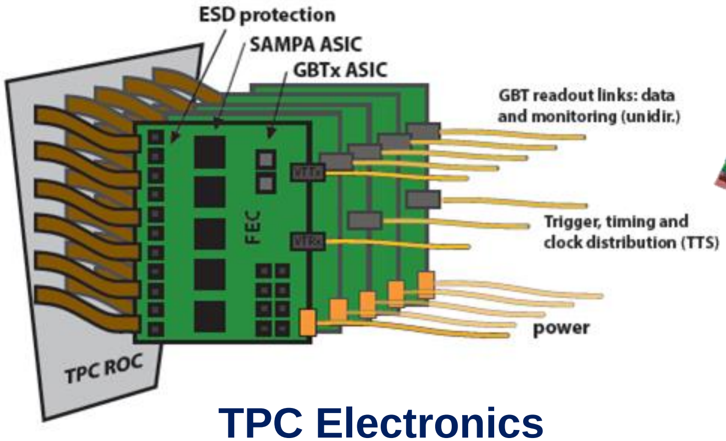
- mapping the character of the hadronic matter under conditions of extreme temperature or net baryon density by varying the temperature of the medium, the virtuality of the probe, and the length scale within the medium
- understanding the parton–medium interactions by studying heavy-flavor jets
- probing the effect of the quark–gluon plasma on the Upsilon states by comparing the p-p (proton-proton), p-A (proton-nucleus), and A-A (nucleus-nucleus) collisions.

ALICE-USA – Targeted Investments

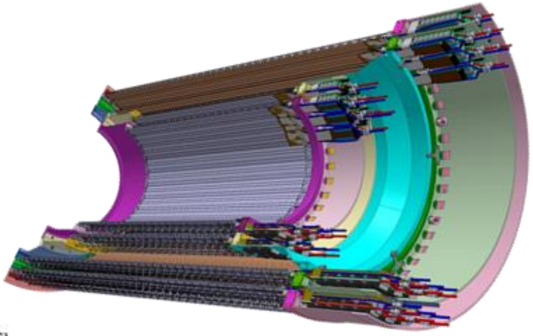


Middle Layer Staves

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

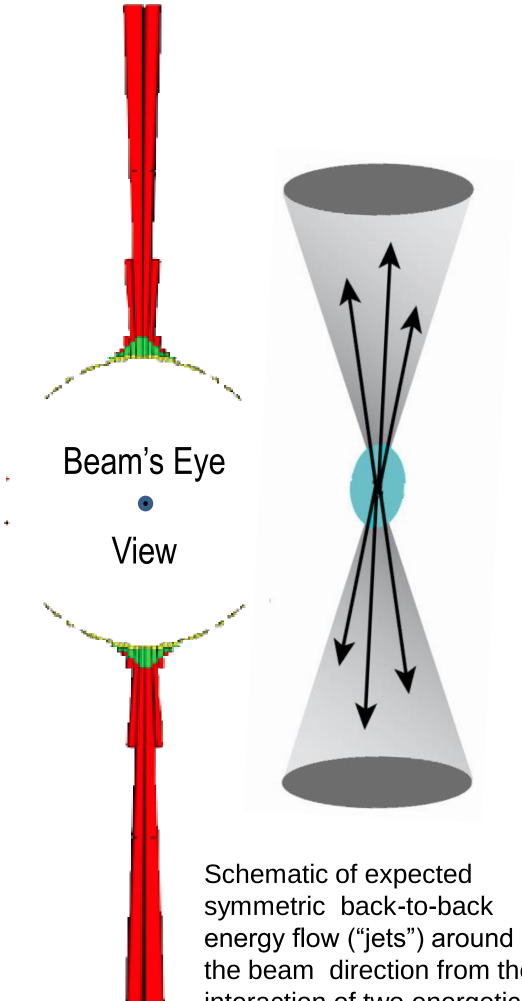


TPC Electronics

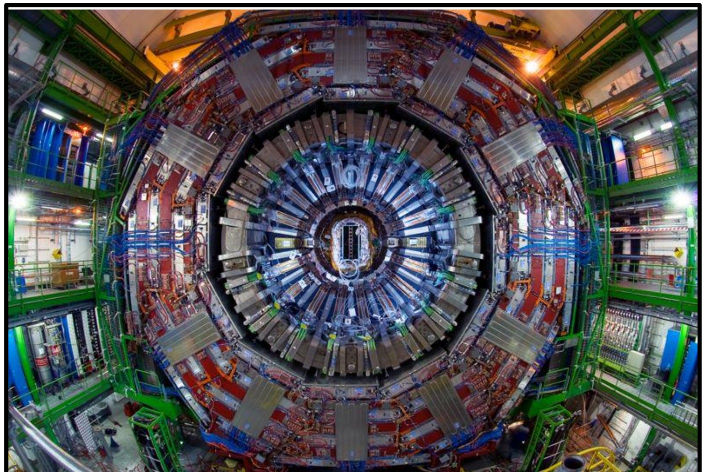


Composite Material Support Structure

Heavy Ion Results at LHC Confirm A New State of Matter is Produced in Relativistic Nucleus-Nucleus Collisions



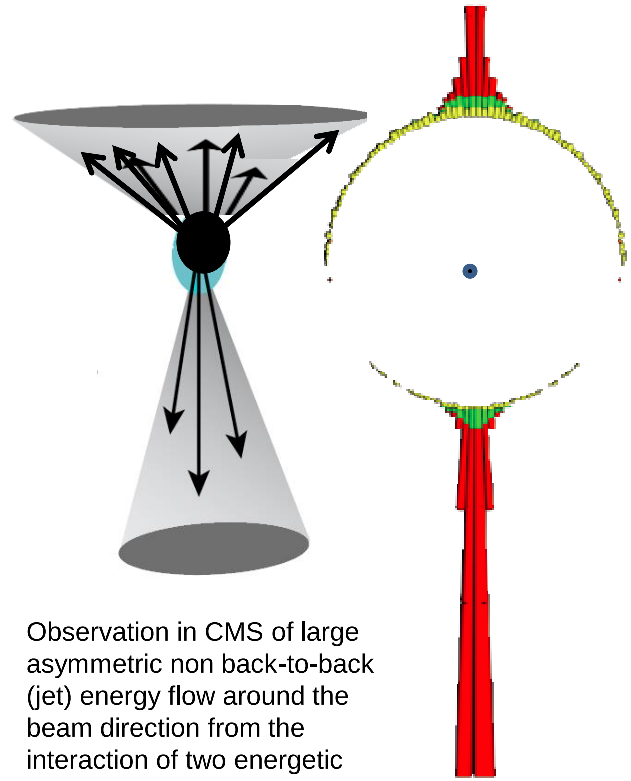
Schematic of expected symmetric back-to-back energy flow ("jets") around the beam direction from the interaction of two energetic partons (quarks, gluons) in proton – proton collisions



Heavy ion data at the LHC indicate a new state of opaque, strongly interacting matter similar to that first discovered at RHIC is produced in heavy ion collisions. "Jets" of energetic particles that traverse the new form of matter are disrupted (right) unlike in proton-proton collisions (left).

The results show that this new form of matter, believed to have influenced the evolution of the early universe, has unique properties and interacts more strongly than any matter previously produced in the laboratory.

Energy deposition in the CMS detector at the Large Hadron Collider (LHC) as a function of angle around the beam direction



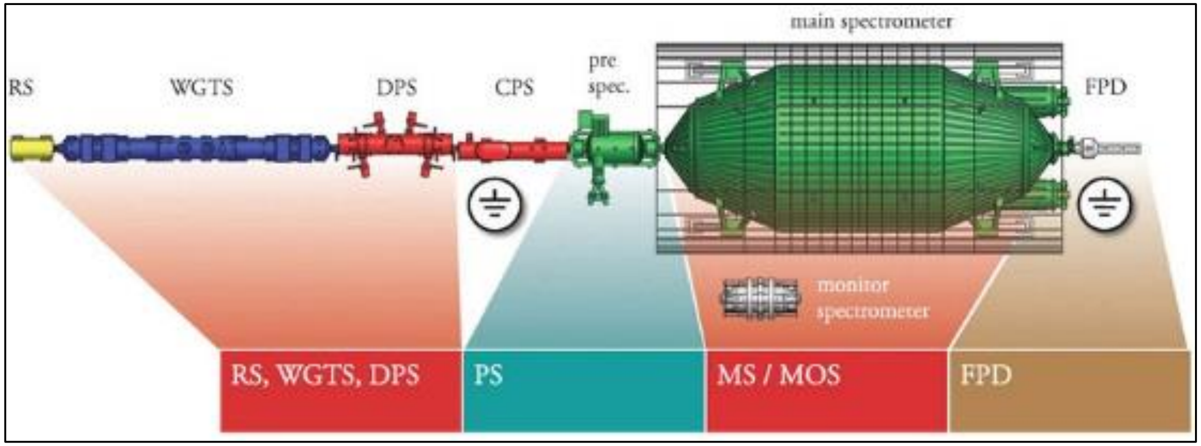
Observation in CMS of large asymmetric non back-to-back (jet) energy flow around the beam direction from the interaction of two energetic partons (quarks, gluons) in relativistic nucleus-nucleus collisions

NP Support for QGP Studies at the LHC

NP plays strong a strong role in heavy ion physics at the LHC

- Strong leadership in science with important results in
  - Relating the “ridge” to higher order flow moments
  - Jet quenching
  - QGP-like flow in small systems
- ALICE (~40 PhD authors)
  - Strong collaboration management participation
  - Lead role in construction and operations of EMCal and Dcal ($13.5M)
  - Operation of two Tier 2 computing sites
  - Major role in Barrel Tracker Upgrade (~$12M)
- CMS (~27 authors)
  - HI program leadership
  - Strong role in trigger for HI with added benefit to HEP program
  - Operation of a Tier 2 computing site
- ATLAS (~8 PhD authors)
  - HI program leadership

First Light at KATRIN

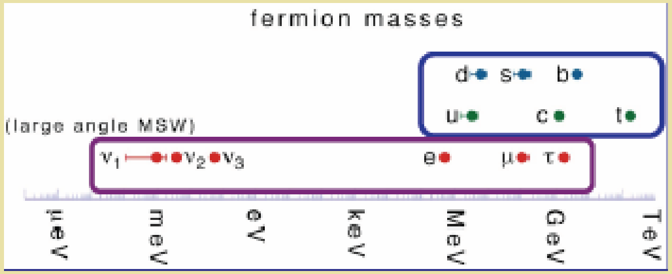


Overview of the 70 m long KATRIN experiment.

0νββ a Science "Must Do" Experiment

What Questions Does It Address ?

- *Is the neutrino its own antiparticle ?*
- *Why is there more matter than antimatter in the present universe?*
- *Why are neutrino masses so much smaller than those of other elementary fermions ?*



Partners

Partners

MAJORANA DEMONSTRATOR

Goal: Demonstrate backgrounds needed for a tonne scale $0\nu\beta\beta$ experiment.

Configuration: 44-kg of Ge detectors, in two independent cryostats

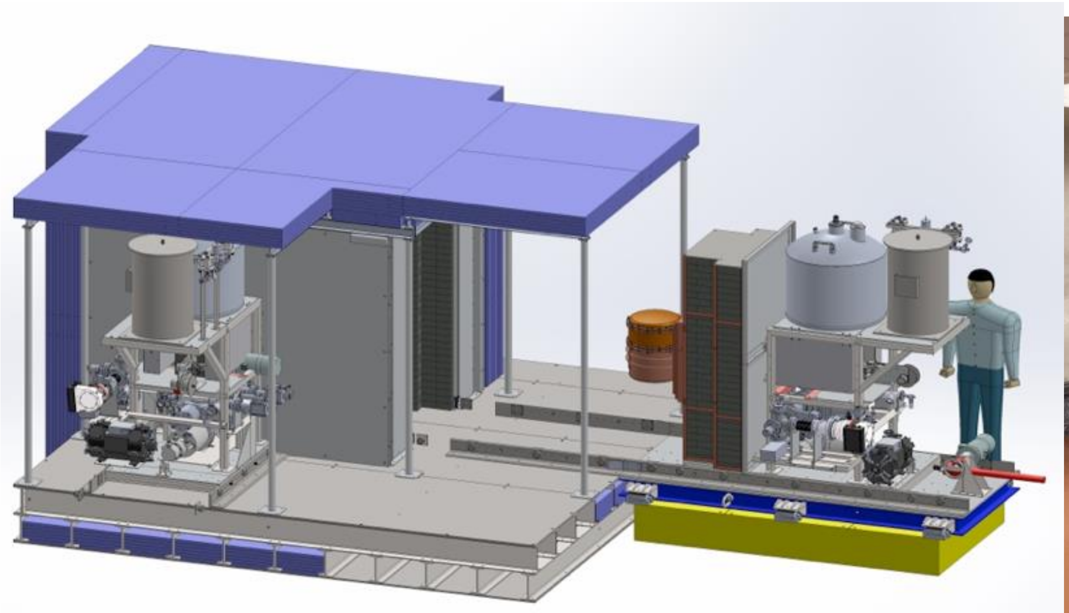
29 kg of 87% enriched ^{76}Ge crystals; 15 kg of ^{nat}Ge, P-type point-contact detectors

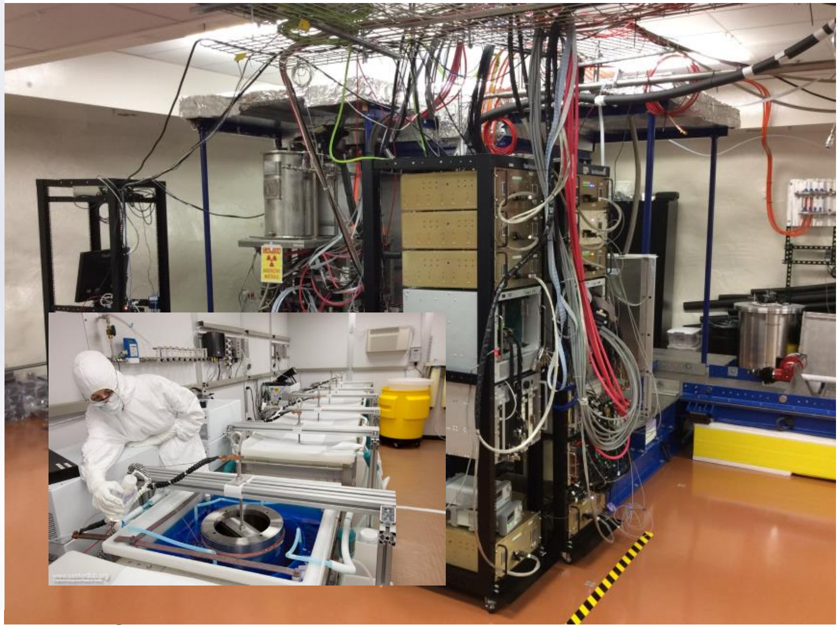
Module One: Installed in-shield and taking low background data since January 2016.

End-to-end analysis underway from to shake down data cleaning and analysis tools (relatively insensitive because of partial shielding) .

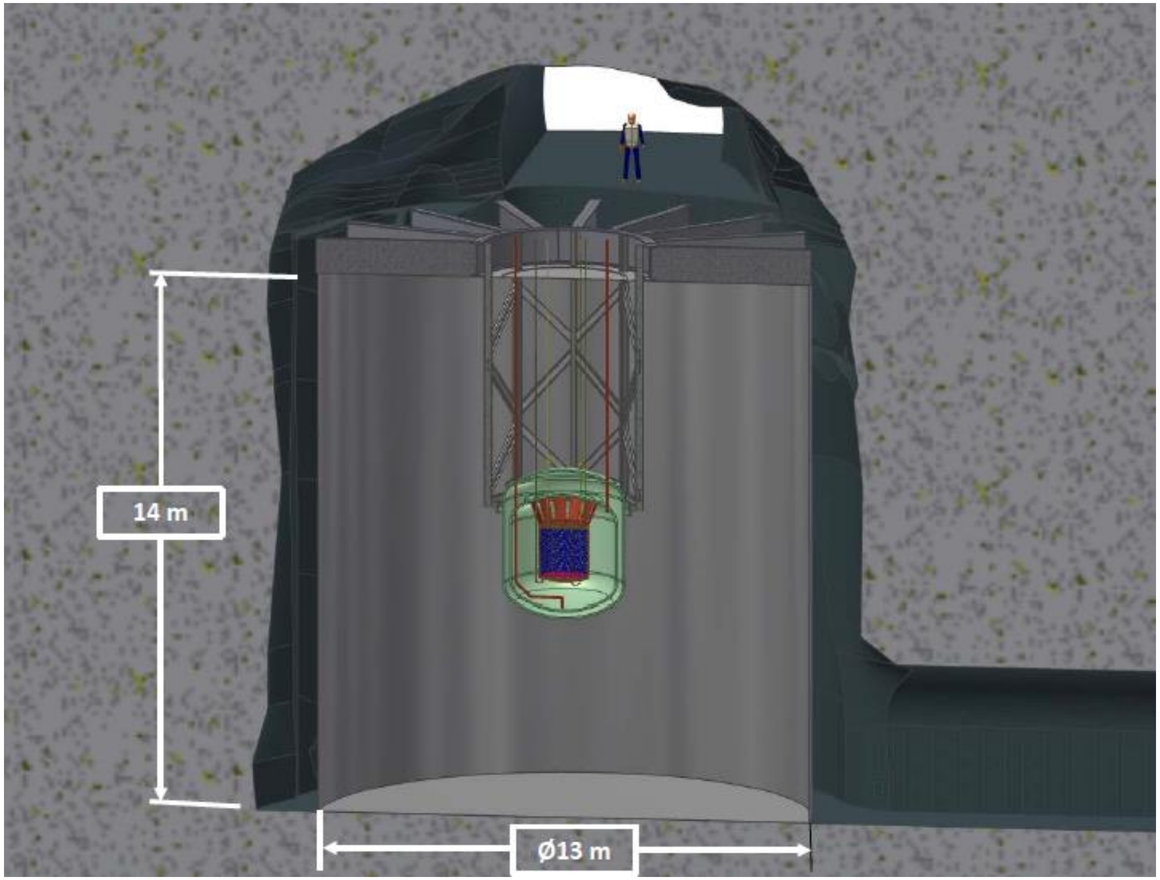
Expect to have first background information from 2016 run in the spring.

Module Two: construction and assembly proceeded on schedule, in-shield commissioning





nEXO Stewardship Transferred to NP in FY2017



IME-CAS (Institute for MicroElectronics of the CAS) has also applied for Collaboration membership

In this figure the nEXO TPC is housed in a large graphite composite cryostat which in turn is submerged in a water shield equipped with photomultiplier tubes to double as a cosmic ray veto detector.

IHEP, Beijing contribution is M&S and 4FTEs towards:

- Charge collection tile hardware
- SiPM and light collection testing
- Simulation of light and charge collection in LXe
- Veto counter hardware
- High resolution ICP-MS for material qualifications (they are finalizing the clean lab for this now)

Nuclear Theory

Maintaining adequate support for a robust nuclear theory effort is essential to the productivity and vitality of nuclear science

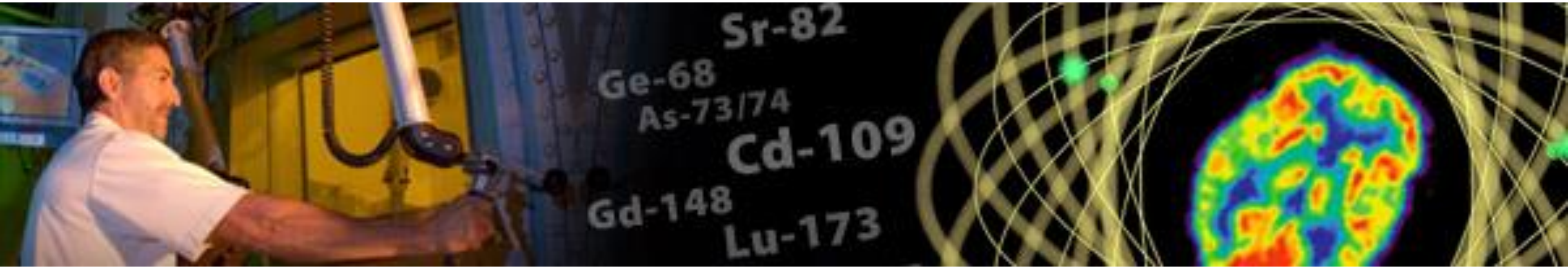
A strong Nuclear Theory effort:

- Poses scientific questions and presents new ideas that potentially lead to discoveries and the construction of facilities.
- Helps make the case for, and guide the design of new facilities, their research programs, and their strategic operations plan.
- Provides a framework for understanding measurements made at facilities and interprets the results.

A highly successful new vehicle for Nuclear Theory was introduced in FY 2012—Theory Topical Collaborations: fixed-term, multi-institution collaborations established to investigate a specific topic:

- A review of the first group of collaborations found that the collaborations presented "… a new direction to enhance the research effort by bundling scientific strength and expertise located at different institutions to reach a broader scientific goal… an extremely promising approach…"
- The first cohort of Topical Theory Collaborations has completed its work. A new cohort will be announced in October 2015.

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

Stable Isotope Production Facility (SIPF) is Part of the FY2017 Request

- Project scope includes procuring and installing additional Electromagnetic Isotope Separator (EMIS) and Gas Centrifuge Isotope Separator (GCIS) machines in an existing building.
- No green site; building modifications may be needed; fabricated as an MIE.
- Hardware designs are known and proven in an existing well proven prototype pilot capability.
- Project received CD0, *Mission Need* on September 4, 2015.

Proposed for Full Funding in FY 2017
Estimated Total Project Cost: \$9.5M-\$10.5M
Estimated time frame for completion: FY 2020

The SIPF directly supports the DOE Isotope Program mission, restoring domestic capability that has been lacking since 1998. Renewed enrichment capability will benefit nuclear and physical sciences, industrial manufacturing, homeland security, and medicine.

Nuclear Physics
FY 2017 House and Senate Marks

Nuclear Physics	FY 2016 Enacted	FY 2017 President's Request	FY 2017 Request vs. FY 2016	FY 2017 House Mark	FY 2017 House vs. Request	FY 2017 Senate Mark	FY 2017 Senate vs. Request	FY 2017 Senate vs. House
Operation and maintenance								
Medium Energy	155,793	163,799	+8,006					
TJNAF Operations	*98,670*	*104,139*	*+5,469*	*104,139*	-			
Heavy Ions	207,910	216,131	+8,221					
RHIC Operations	*172,088*	*179,700*	*+7,612*	*179,700*	-	***179,700***	-	-
Low Energy	78,785	79,893	+1,108					
ATLAS Operations	*18,199*	*19,199*	*+1,000*					
Nuclear Theory	45,775	46,465	+690					
Isotope Program	21,337	29,370	+8,033					
Undistributed	-	-	-	*236,161*		*355,958*		
Total, Operation and maintenance	**509,600**	**535,658**	**+26,058**	**520,000**	**-15,658**	**535,658**	**-**	**+15,658**
Construction								
14-SC-50 Facility for Rare Isotope Beams	100,000	100,000	-	**100,000**	-	**100,000**	-	-
06-SC-01 12 GeV CEBAF Upgrade	7,500	-	-7,500	-	-	-	-	-
Total, Construction	**107,500**	**100,000**	**-7,500**	**100,000**	**-**	**100,000**	**-**	**-**
Total, Nuclear Physics	**617,100**	**635,658**	**+18,558**	**620,000**	**-15,658**	**635,658**	**-**	**+15,658**

Additional Comments on Budget

- House Mark provides $620M, $15.7M below the request. Total reduction of $17M
- $100M is specified for construction of FRIB, as requested.
- RHIC operates for 24 weeks, JLAB: operates for 26 weeks

- Senate Mark provides $635.7M, the same as the President's Request.
- Senate Mark supports implementation of the world-leading program of nuclear science envisioned in NSAC's 2015 Long Range Plan for Nuclear Science

Outlook

- The CEBAF and RHIC programs 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. It is not too soon to begin to position the low energy community to take full advantage of FRIB as soon as it becomes operational.
- 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
- An equally high priority for the NP community is increasing investment in research and projects as a percentage of the total NP budget. This will have to be accomplished while still respecting the unitarily limit.
- 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