U.S. DEPARTMENT OF ENERGY | Office of Science

Frontiers, Challenges, and Opportunities in U.S. Nuclear Science

Low Energy Community Meeting

Notre Dame, South Bend IN, August 12, 2016

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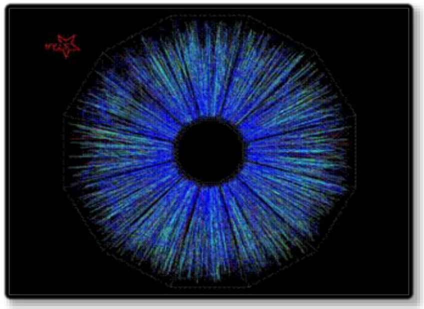
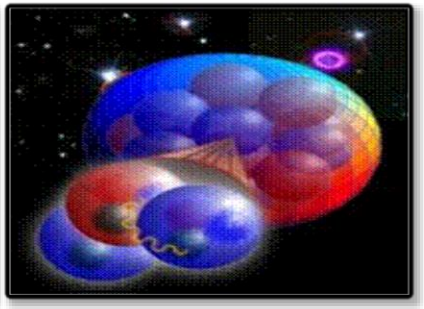
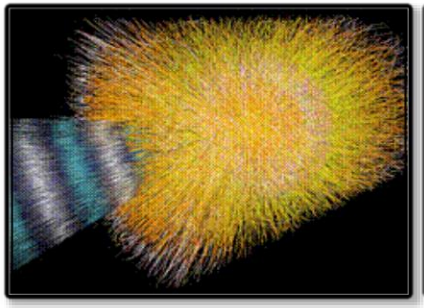
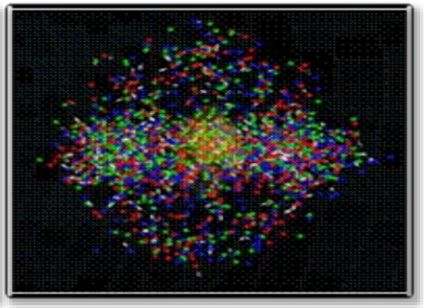
DOE Office of Science

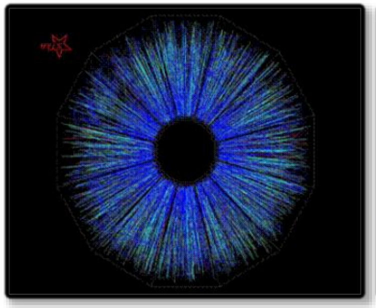
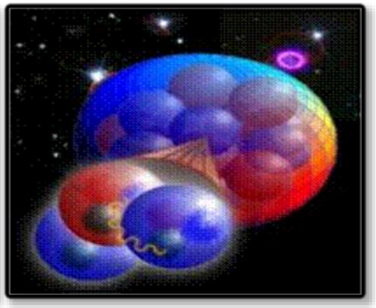
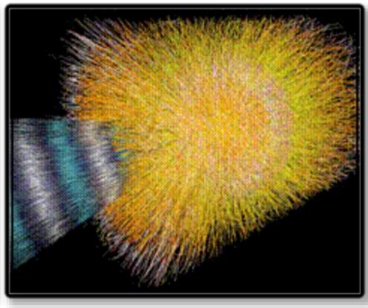
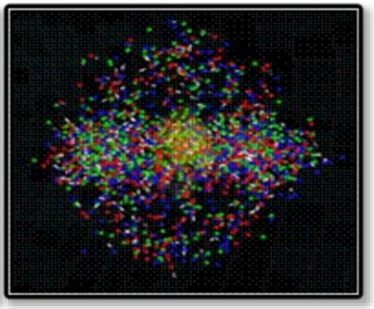





Three Broad Scientific Thrusts of U.S. Nuclear Science

Quantum Chromodynamics (QCD) seeks to develop a complete understanding of how quarks and gluons assemble themselves into protons and neutrons, how nuclear forces arise, and what forms of bulk strongly interacting matter can exist in nature, such as the quark-gluon plasma.

Nuclei and Nuclear Astrophysics seeks to understand how protons and neutrons combine to form atomic nuclei, including some now being observed for the first time, and how these nuclei have arisen during the 13.8 billion years since the birth of the cosmos.

Fundamental Symmetries of neutrons and nuclei seeks to develop a better understanding of fundamental interactions by studying the properties of neutrons and targeted, single focus experiments using nuclei to study whether the neutrino is its own anti-particle.

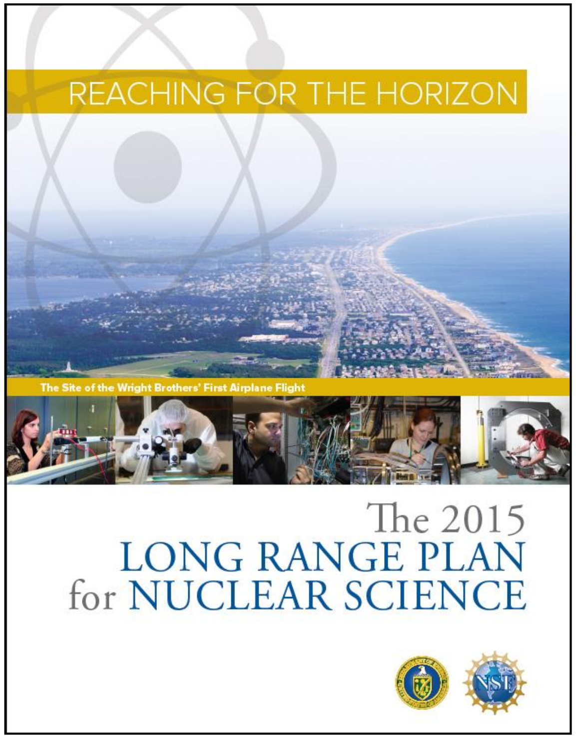





The 2015 Long Range Plan for Nuclear Science

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:

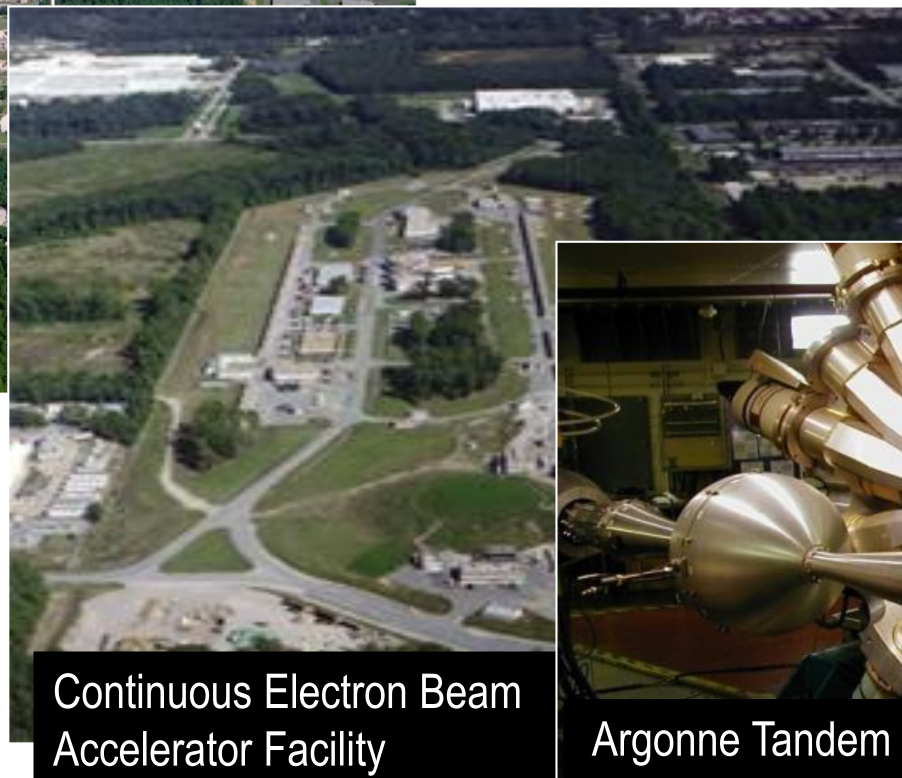
- The progress achieved under the guidance of the 2007 Long Range Plan has reinforced U.S. world leadership in nuclear science. ***The highest priority in this 2015 Plan is to capitalize on the investments made.***
- The observation of neutrinoless double beta decay in nuclei would…have profound implications.. ***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.***

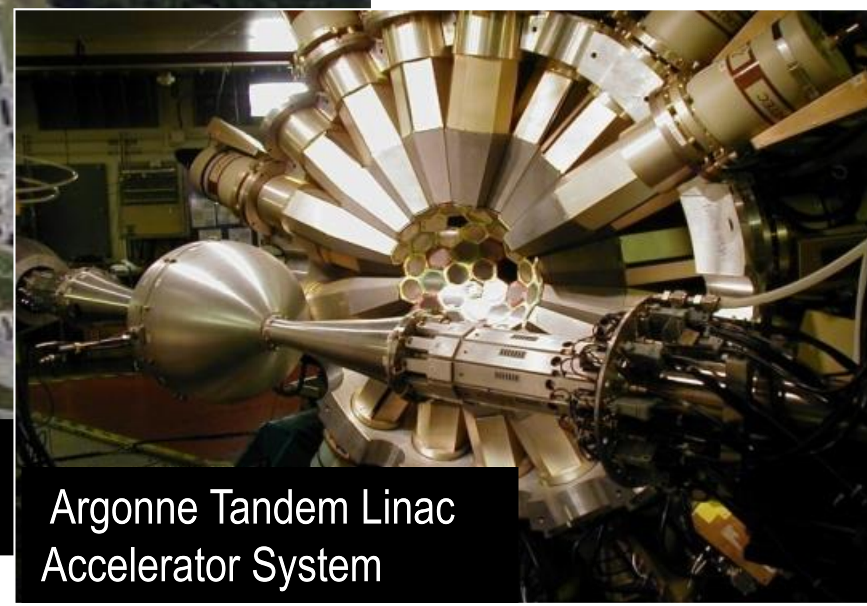


NP is implementing these recommendations which are supported in the President's FY 2017 request

Current U.S. NP National User Facilities

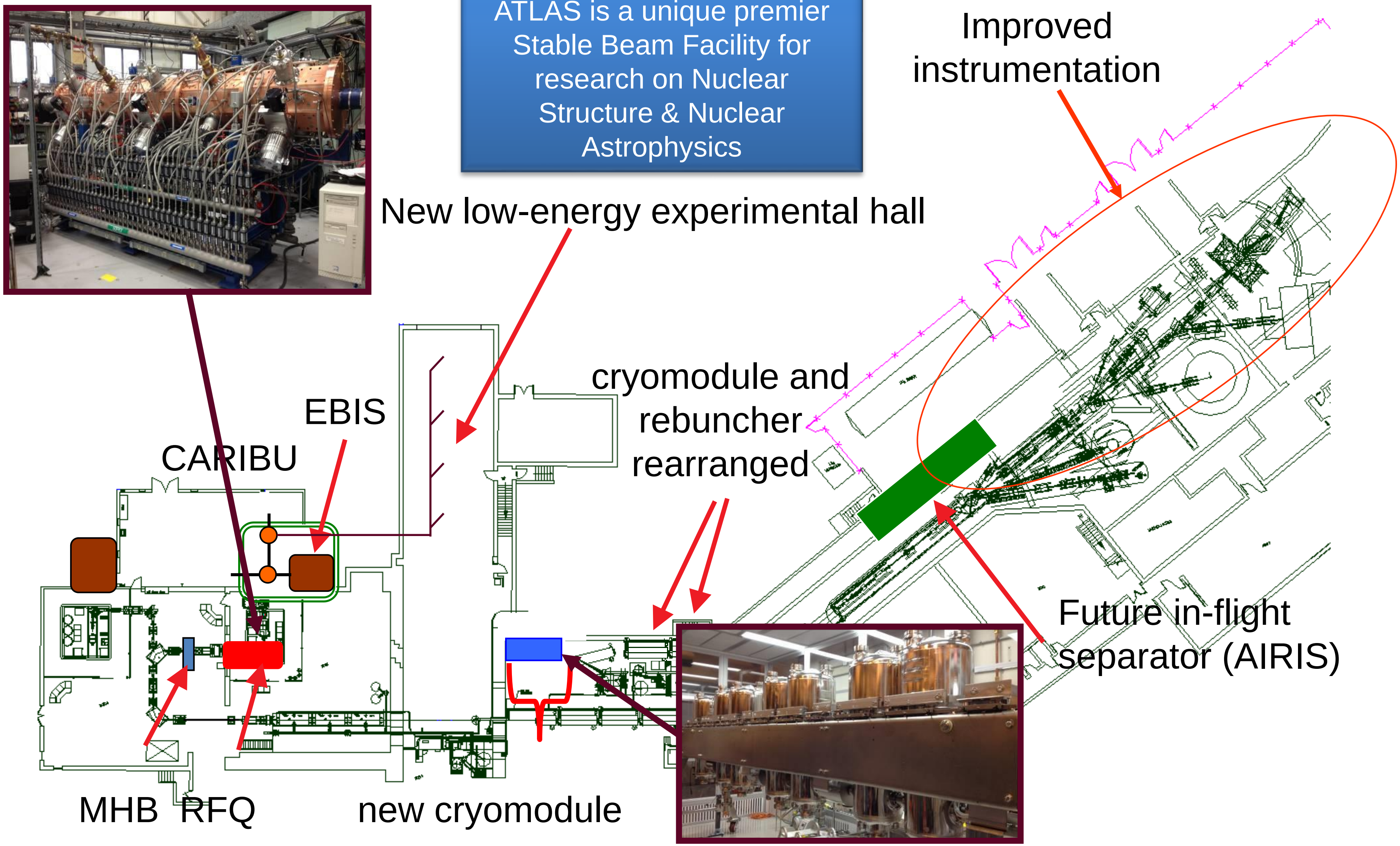
"Microscopes" pursuing groundbreaking research





ATLAS Layout After Recent Upgrades

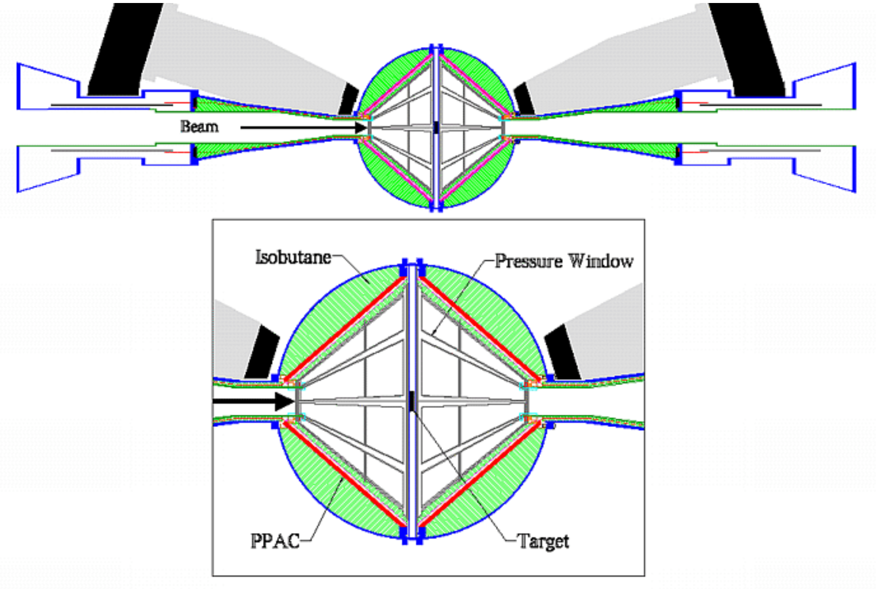
ATLAS is a unique premier Stable Beam Facility for research on Nuclear Structure & Nuclear Astrophysics



CHICO-II and GRETINA at ATLAS

Programs:

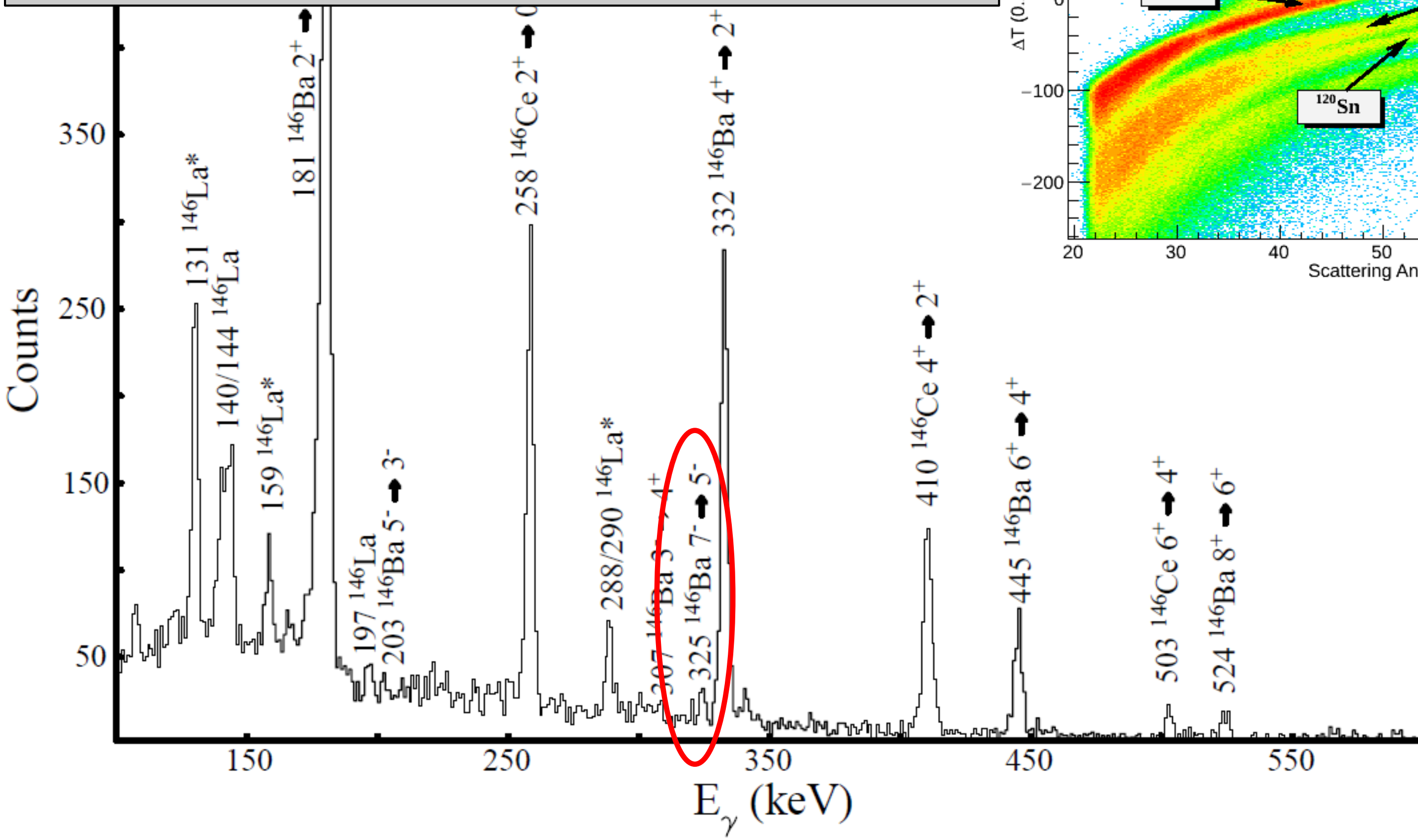
- Coulomb Excitation of stable and CARIBU beams;
- Structure studies of neutron-rich nuclei using deep-inelastic reactions;
- CHICO-II: high segmentation for both θ (1°) and ϕ (1.4°)
- GRETINA: about 3.50(2)% absolute efficiency at 1332.5 keV

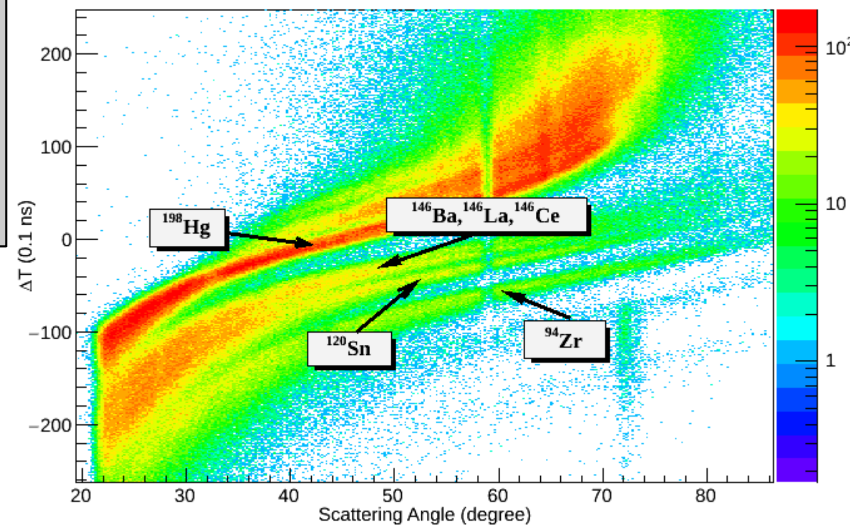


^{146}Ba Coulomb Excitation

Statistics ~ 100 times higher than previously obtained

- higher yield
- more stable operation
- more efficient post-acceleration
- better diagnostics

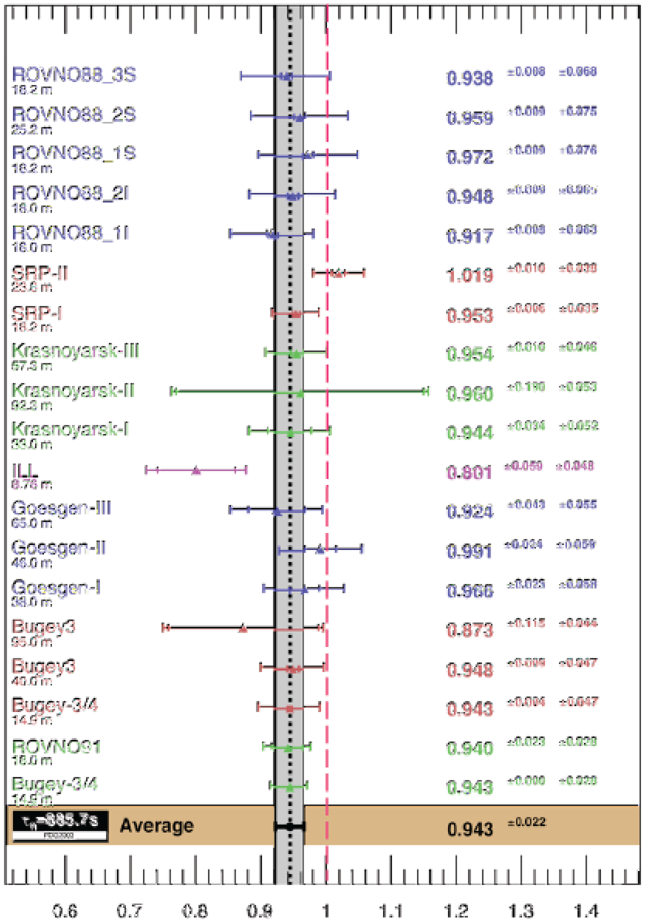




^{146}Ba is predicted to octupole deformed. The observed coincidence γ spectra allow extraction of an E3 transition probability to verify the theory.

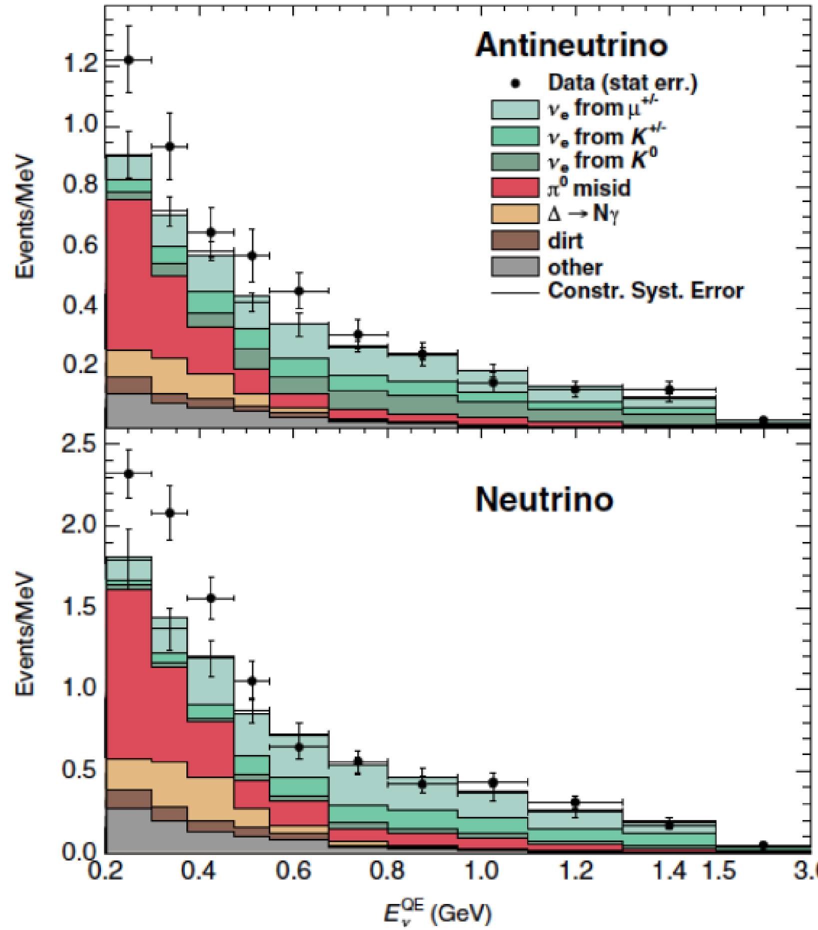
Nuclear Data Connection Between Discovery Research, Decay Heat, and Fission Yields

Reactor Anti-Neutrino Anomaly



ν Measured / ν Expected

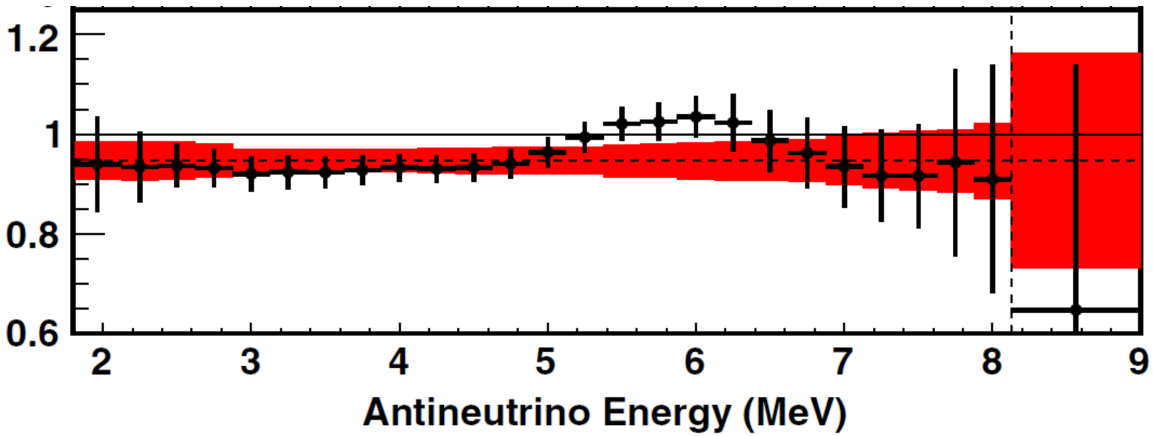
Mini-Boone Oscillation Data



New physics (e.g. a sterile neutrino) or wrong prediction of neutrino spectra ?

β-decay studies of Fission Products with the Modular Total Absorption Spectrometer (MTAS) and the Versatile Array for Neutrons at Low Energy (VANDLE) at ORNL's Tandem-ISOL

- The measured reactor anti-neutrino spectra show only about 95(2)% of total expected events ("reactor anti-neutrino anomaly" Huber-Mention 2011) and an about 10% enhancement of signals at 5 to 7 MeV energy, see, e.g., Fig 3 from *An et al., PRL 116, 061801, 2016* given below.



- It might be a sign for new fascinating physics or for incomplete data contributing to the modeled reactor antineutrino spectrum.

Science goal:

Obtain reliable β-decay data for complex decays of fission products to deduce reactor anti-neutrino energy spectrum and decay heat.

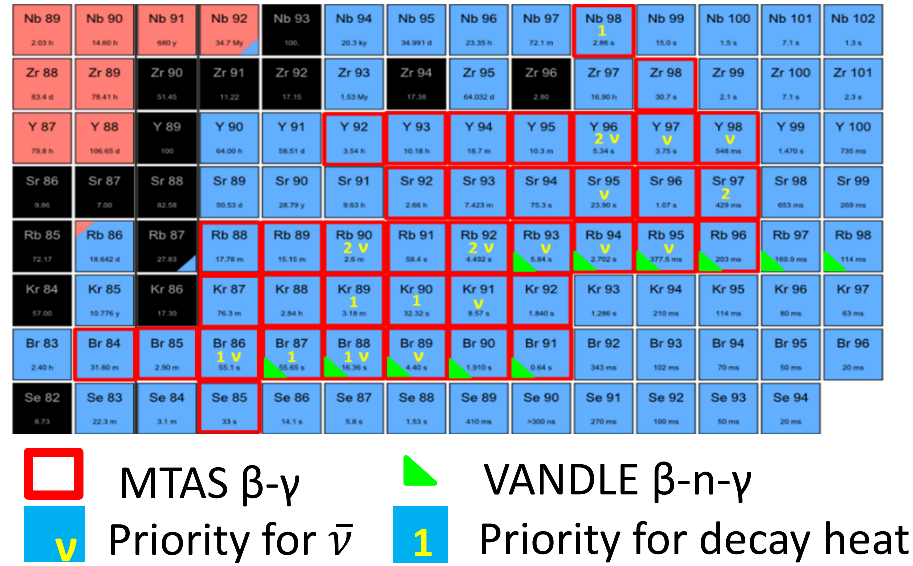
MTAS Results

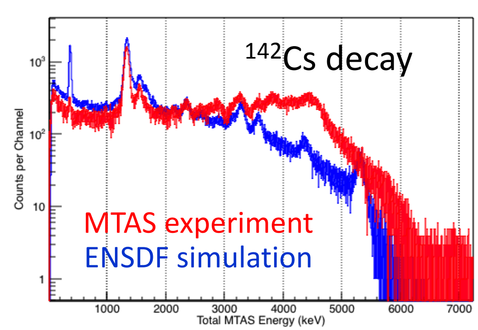
Over 70 decays measured: 64% of direct production and 34% of cumulative yield in $^{235}U+n_{th}$ fission.

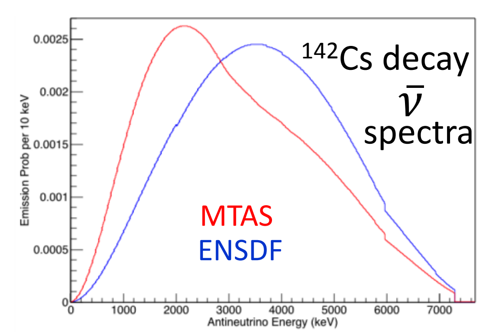
Evaluation of 8 activities, ^{86}Br, ^{89}Kr, ^{89}Rb, ^{90}Kr, $^{90m,gs}Rb$, ^{92}Rb and ^{139}Xe, yielded a reduction of the overall reactor anti-neutrino interactions by 1.2% for LEU power reactors and 1.5% for HEU research reactor like HFIR, when MTAS data replace respective entries in ENSDF.

The reported 95(2)% anomaly is reduced, correspondingly. *[Fijałkowska et al.,2016]*

MTAS data on the top three activities contributing to the enhancement of anti-neutrino signals at 5-7 MeV, ^{92}Rb, ^{96}Y and ^{142}Cs, increases this ~ 10% effect to about 12%. *[Rasco, Wolińska et al., 2016]*







MTAS spectra of ^{142}Cs decay and anti-neutrinos emitted from ^{142}Cs. Red lines are MTAS data, blue lines are based on present ENSDF data. The MTAS data points to a shift of the ^{142}Cs decay to higher excited states and hence the anti-neutrino spectrum shifts towards lower energies.

Conclusion from MTAS measurements:

- "reactor anti-neutrino anomaly" is reduced
- high energy "anti-neutrino bump" is enhanced
- decay heat is enhanced

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

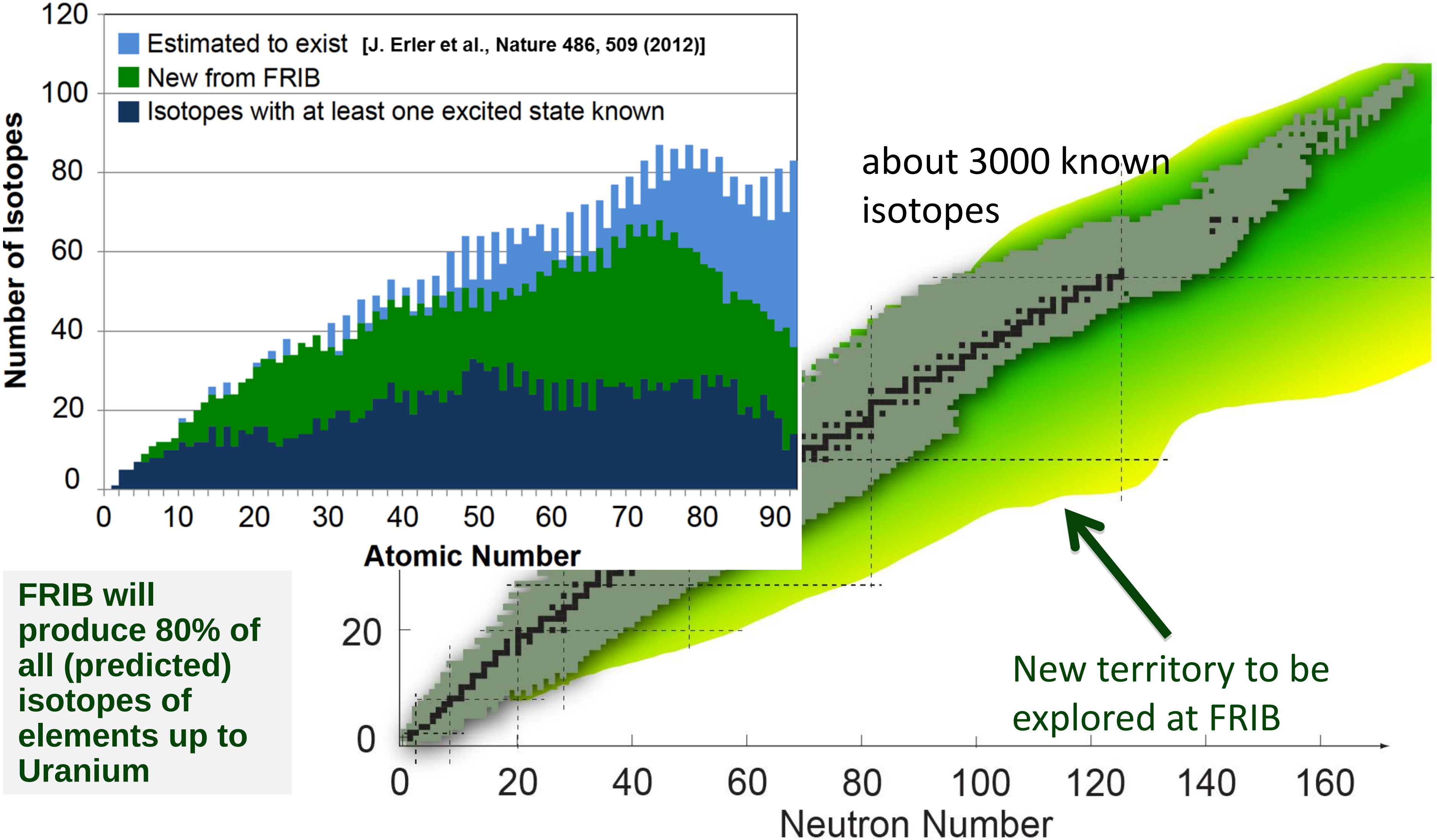
Fundamental Symmetries

- 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

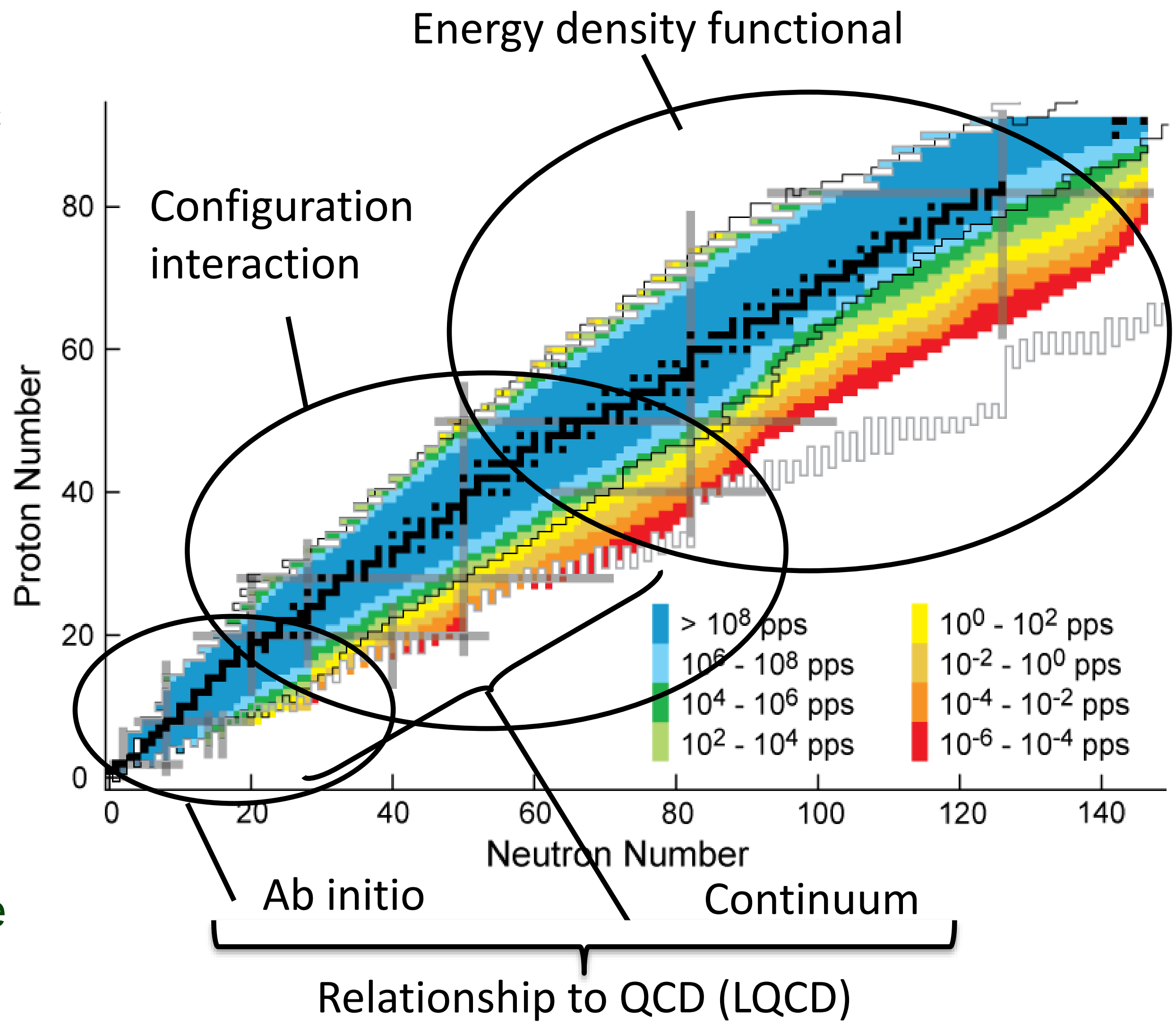
FRIB Discovery Potential – New Phenomena and Topologies To Discover



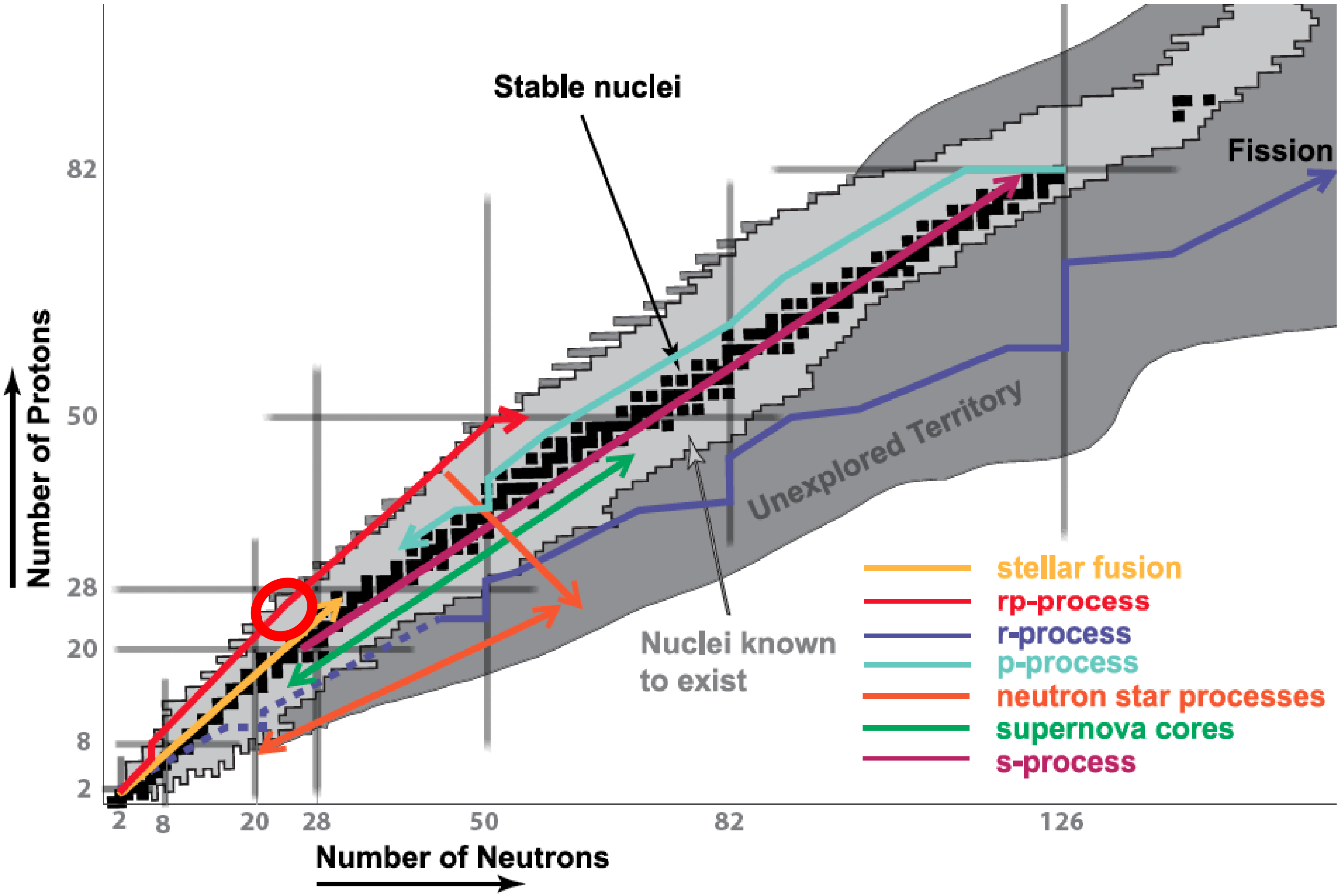
FRIB will produce 80% of all (predicted) isotopes of elements up to Uranium

Lofty Goal: Comprehensive Model of Nuclear Structure and Reactions

- A comprehensive and quantified model of atomic nuclei does not yet exist
- In recent years, enormous progress has been made with measurements of properties of rare isotopes and developments in nuclear theory and computation
- Access to key regions of the nuclear chart constrains models and identifies missing physics
- Theory identifies key nuclei and properties to be studied

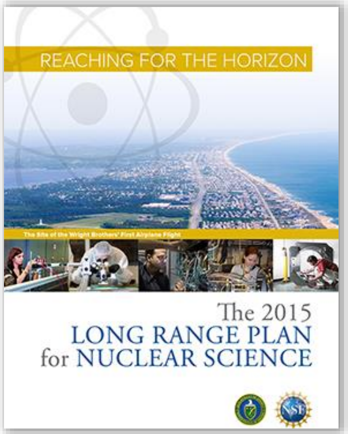


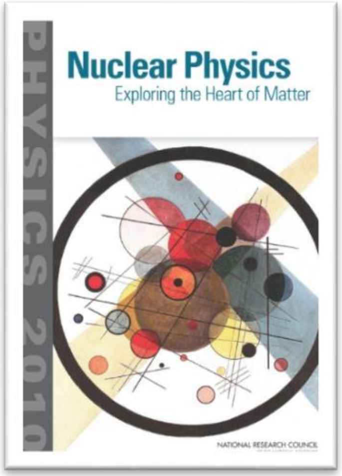
Rare Isotopes are Important to Understand Astrophysical Scenarios



FRIB Will Usher in a New Era in NP Where Key Rare Isotopes Can be Produced and Studied

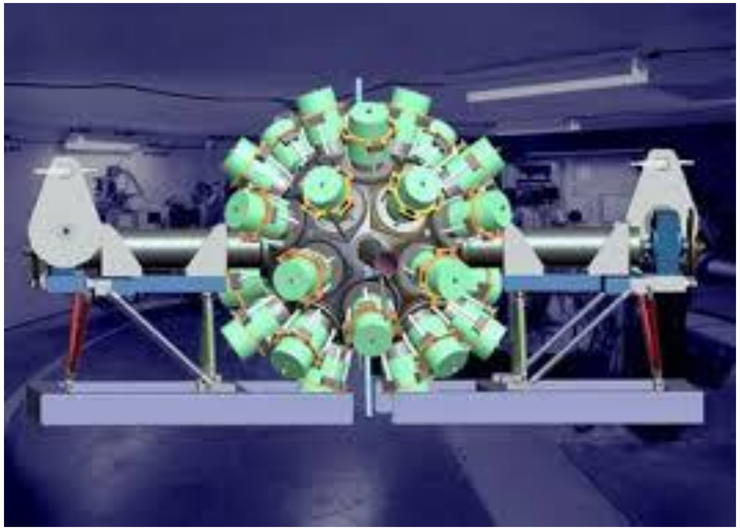
- **Development of a predictive model for nuclei**
  - What combinations of protons and neutrons can be made into abound system? What is the nature of the nuclear force?
  - Data from FRIB will tell
- **Foundation for astrophysical modeling**
  - Access to key data needed to understand the origin of the elements in nucleosynthesis processes
- **Search for symmetry violations, e.g. atomic EDMs**
  - Manifold opportunities at FRIB to contribute to the hunt for physics beyond the Standard Model
- **Applications of rare isotopes**
  - Unique opportunities to provide research quantities of rare isotopes to other communities (in commensal operation or targeted)



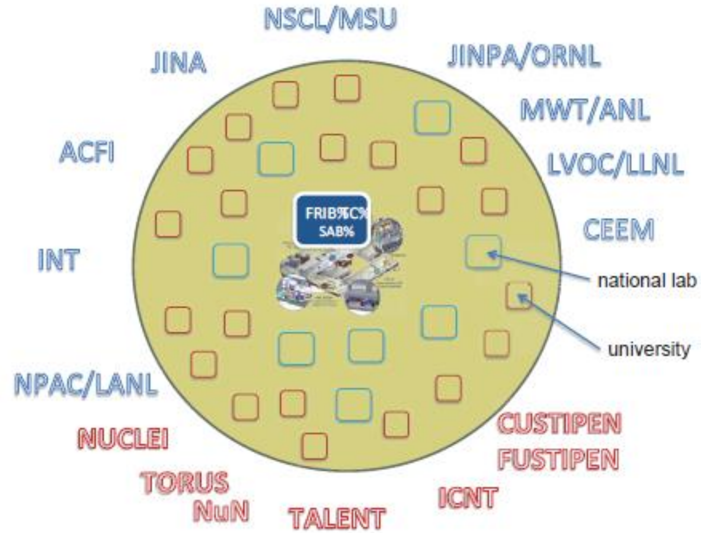


Enormous discovery potential!

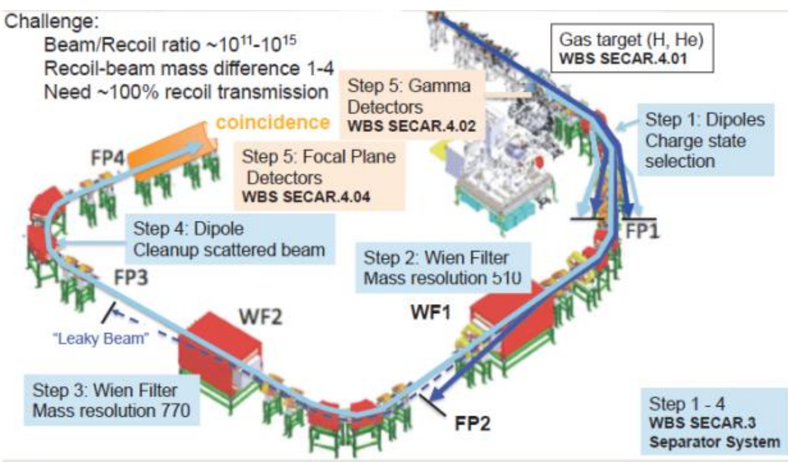
FRIB Instrumentation/Theory Effort is Underway



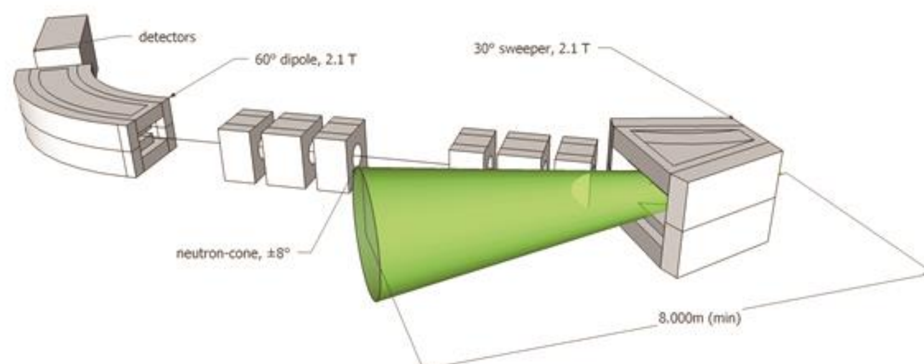
GRETA



FRIB Theory Alliance



SECAR



Pre-Conceptual High Rigidity Spectrometer (HRS)

Fundamental Symmetries in DOE NP:

Topics where nuclear science contributes uniquely to knowledge, experimental techniques or both

Topics that are non-overlapping with DOE HEP

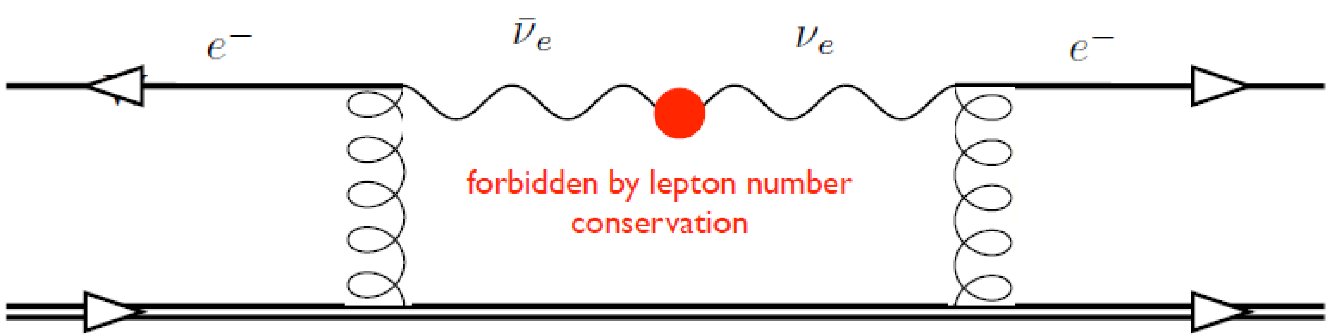
A High Priority NP Frontier: Neutrino-less Double Beta Decay

Three Light Neutrinos: What Do We Know ?

2ν DBD: $A(Z,N) \rightarrow A(Z+2, N-2) + e^- e^- \nu\,\nu$

If own antiparticle, can be emitted then absorbed during decay

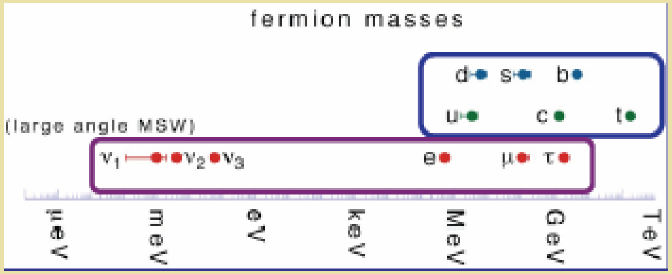
0ν DBD: $A(Z,N) \rightarrow A(Z+2, N-2) + e^- e^-$



Why Is 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 Progess

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

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

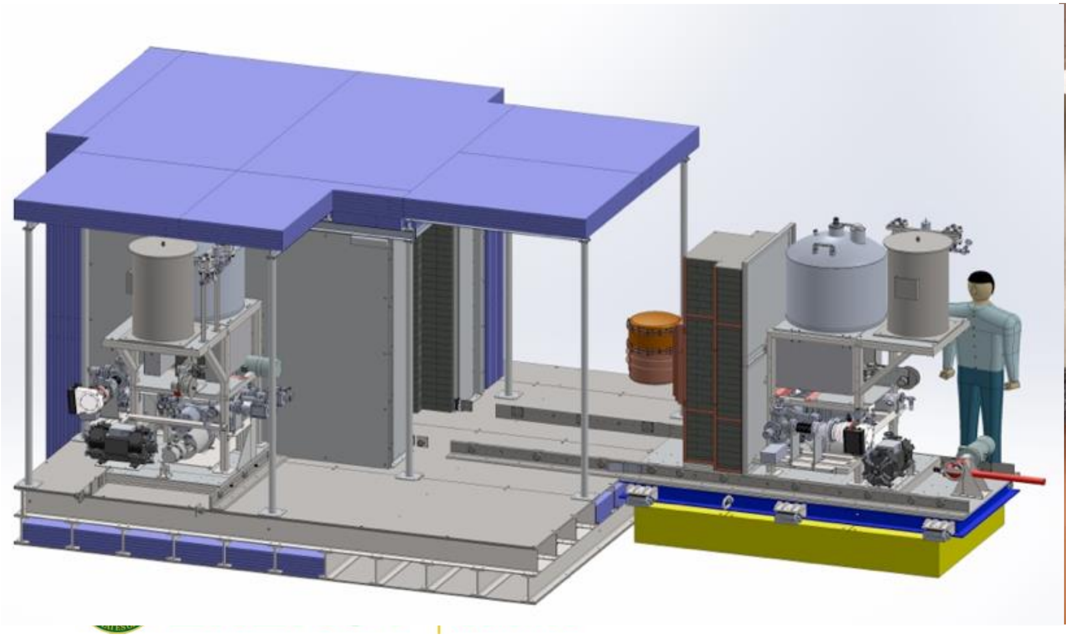
29 kg of 87% enriched ^{76}Ge crystals; 15 kg of ^{nat}Ge, P-type point-contact detectors

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

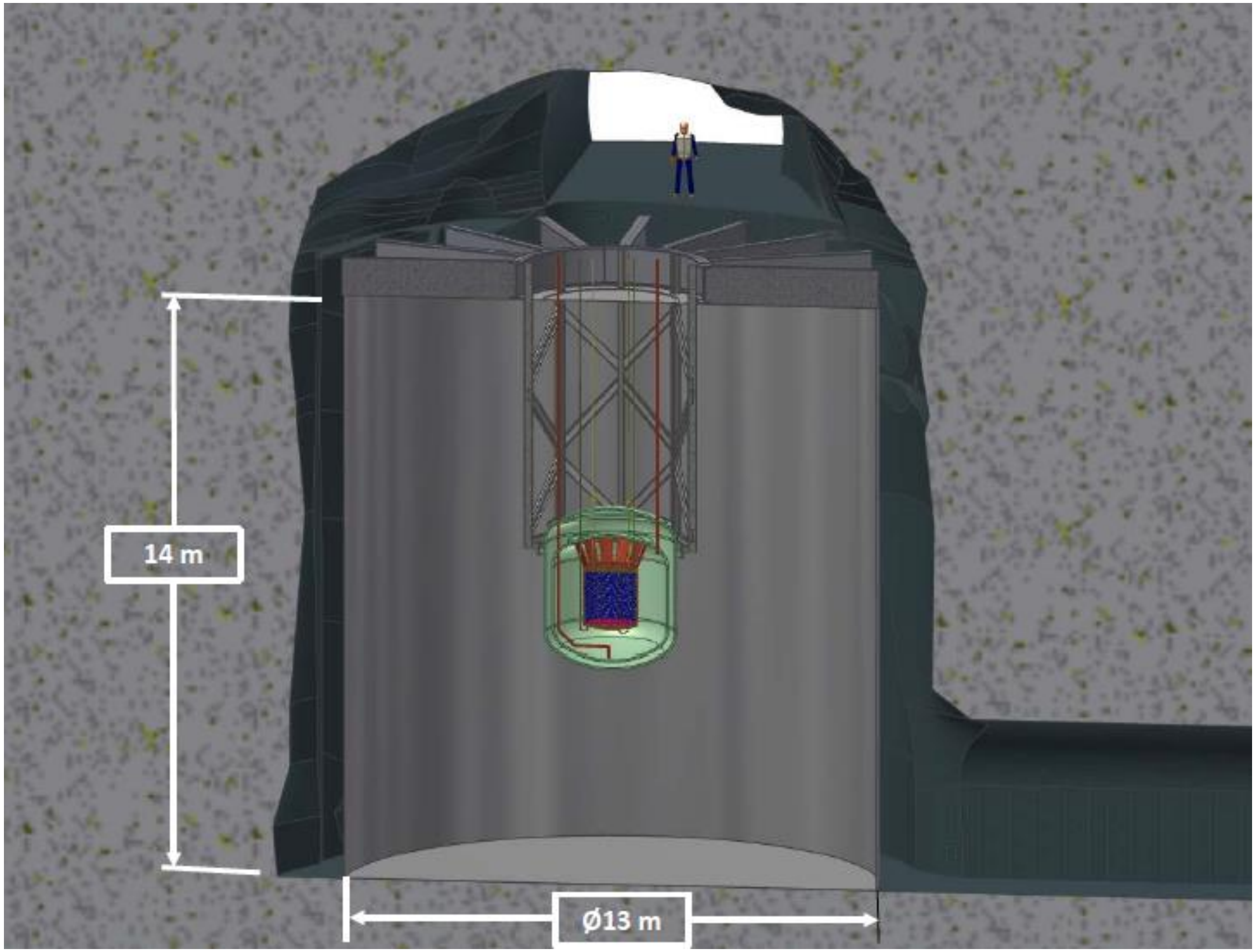
End-to-end analysis underway from July - Oct. 2015 dataset to shake down data cleaning and analysis tools (relatively insensitive because of partial shielding) .

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

Module Two: construction and assembly proceeding on schedule, in-shield commissioning beginning ~ May 2016



nEXO Stewardship Transferred to NP in FY2017



Artist's concept of the nEXO detector in SNOLab's. In this model the 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.

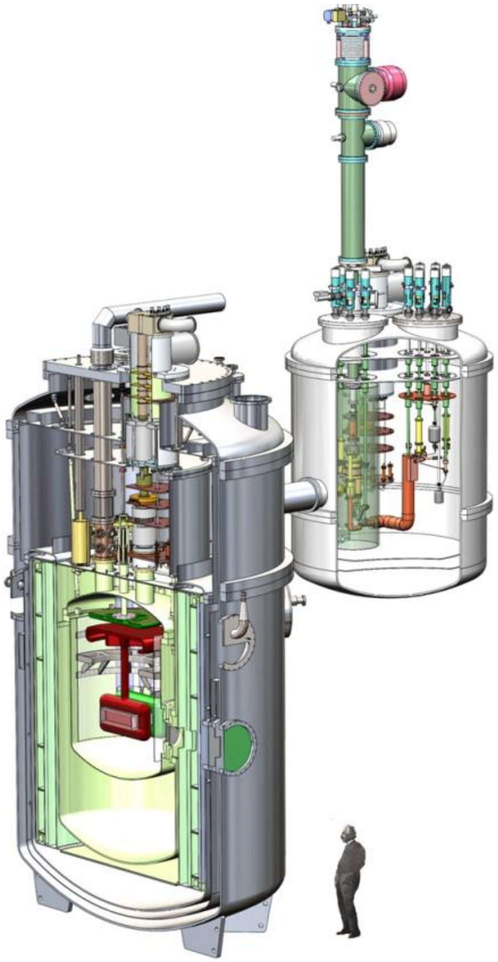
Progress on nEDM at the Spallation Neutron Source

- Completed half of 4-year Critical Component Demonstration (CCD) program

  Goal: reduce technical risk by demonstrating full-scale modules at operating conditions

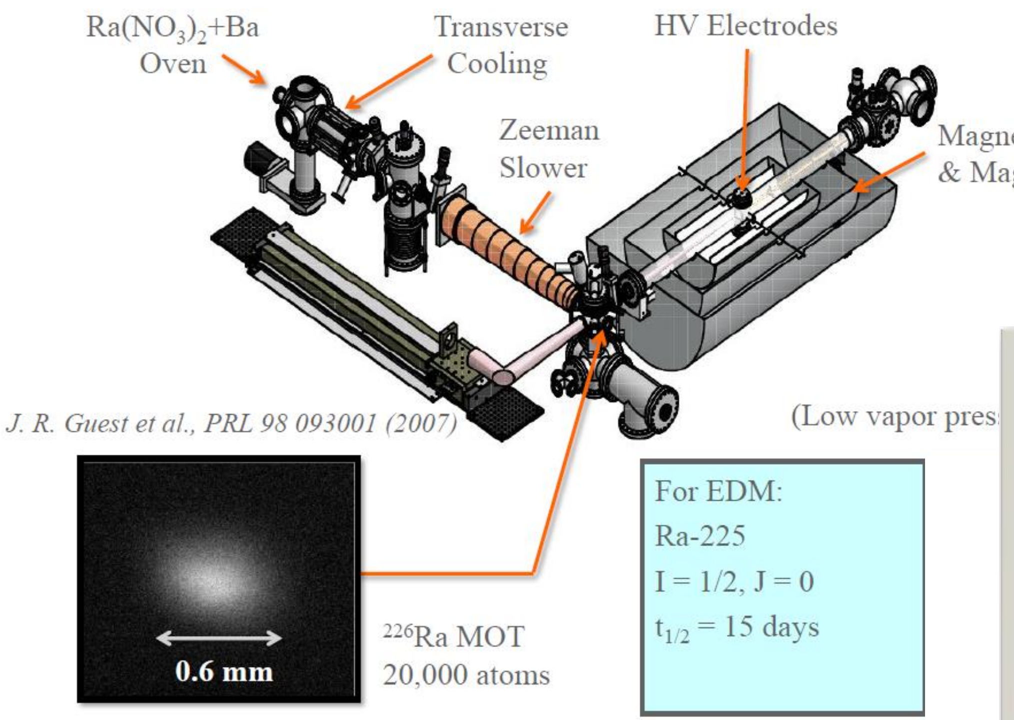
  - High-power non-magnetic dilution refrigerator
  - Polarized Helium-3 (co-magnetometer) injection/transport
  - Magnet coil package
  - High-voltage
  - Ultracold neutron storage
  - Light collection system

- To be followed by Large Subsystem Integration (LSI) (assembling the modules into a complete experiment) and Conventional Component Procurements (CC)



^{225}Ra EDM Experiment: New Results

Collect Atoms in MOT

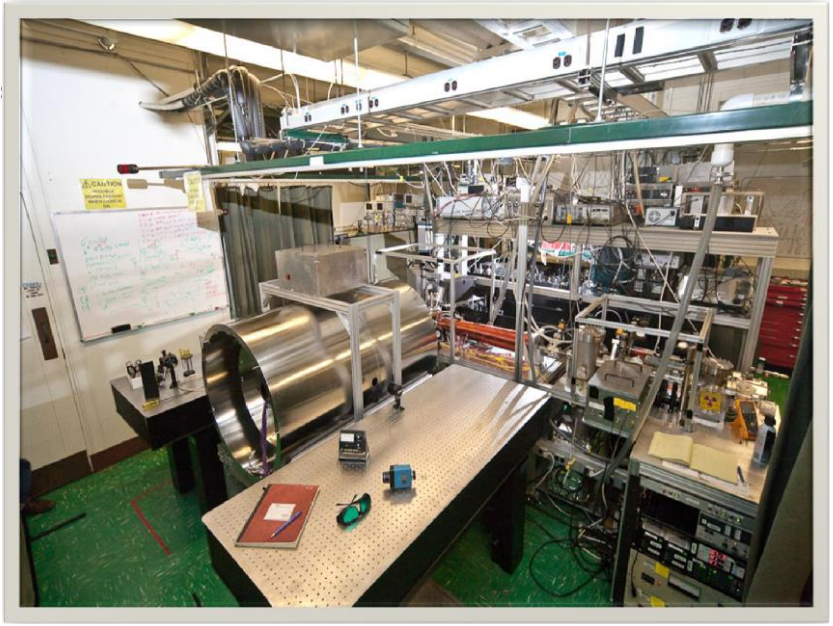


2014: First ^{225}Ra measurement M. Dietrich *et al.*, PRL 114, 233002 (2015)

2015: Updated measurement: factor of 35 improvement

$|d| < 1.4 \times 10^{-23}$ e cm

M. Bishof *et al.*, PRC 94, 025501 (2016).



ANL, MSU, USTC and Kentucky

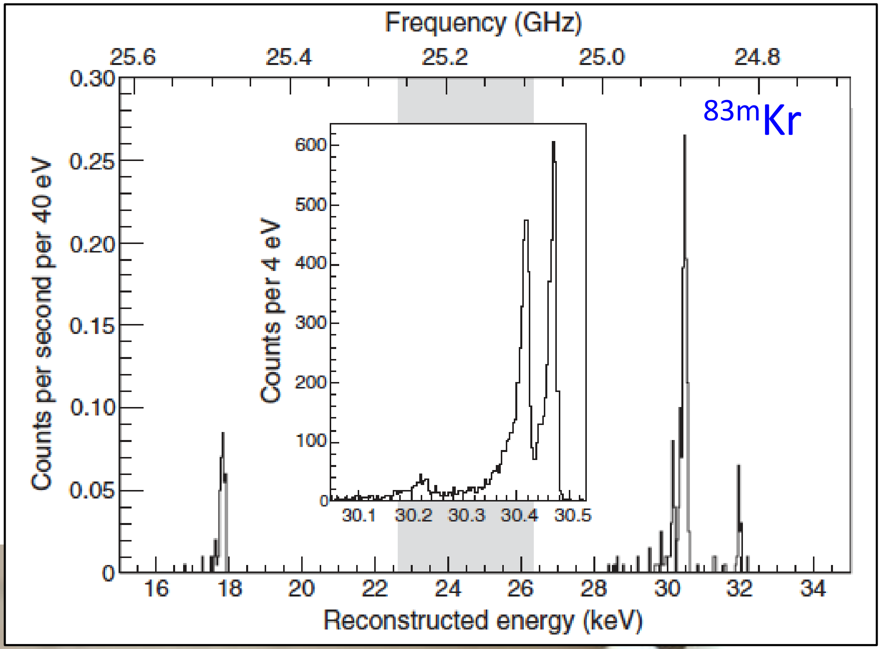
PROJECT 8

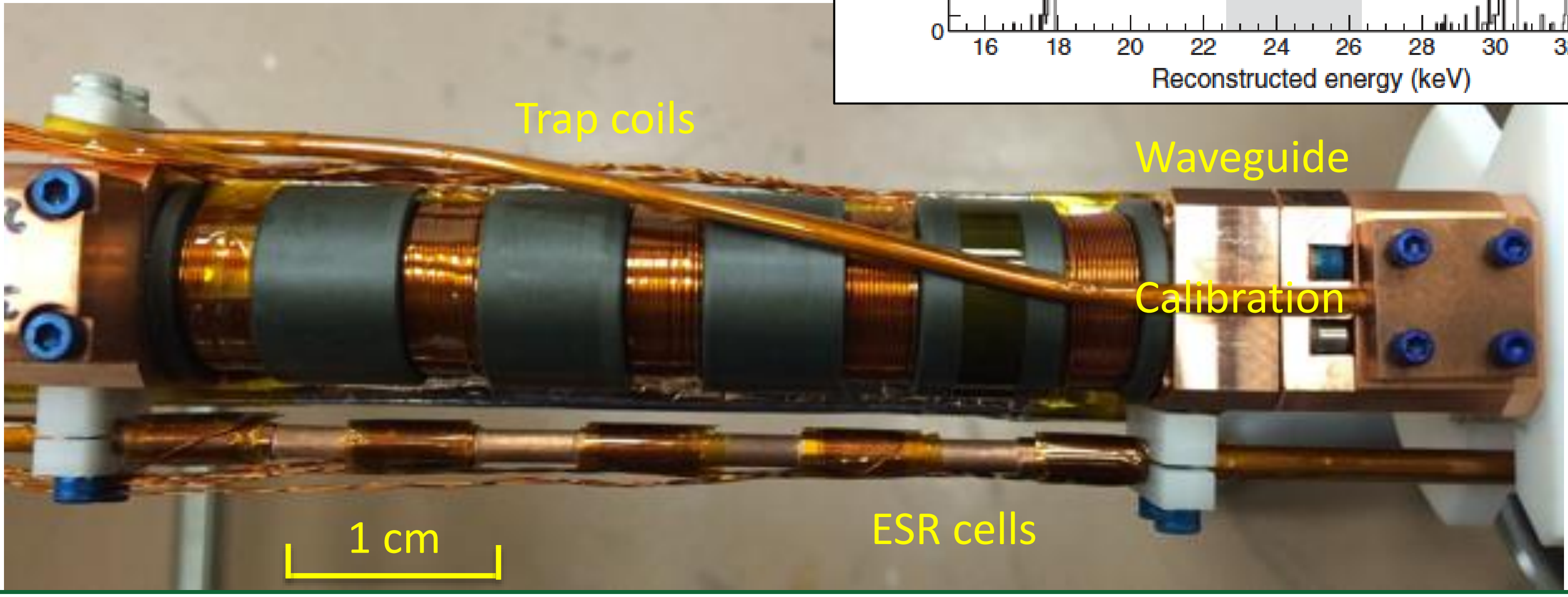
A Potential Major Advance On Measuring m_ν

A new concept for direct measurement of neutrino mass by observation of cyclotron radiation in tritium beta decay.

Successful proof of concept with ^{83m}Kr: PRL 114, 162501 (2014).

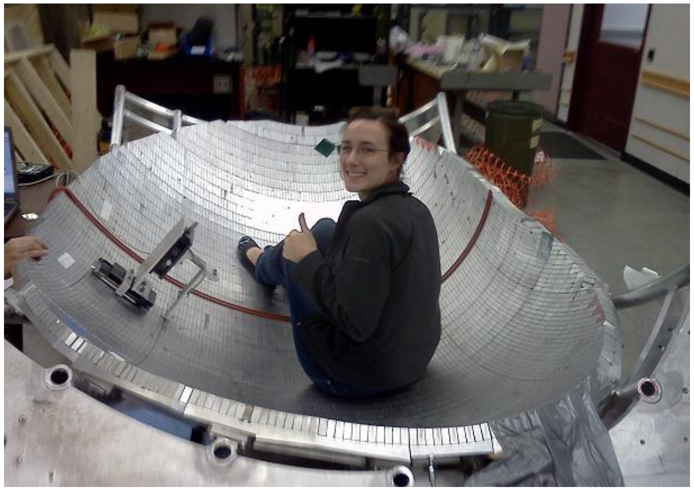
26-GHz tritium cell ready for first data – larger systems to follow.



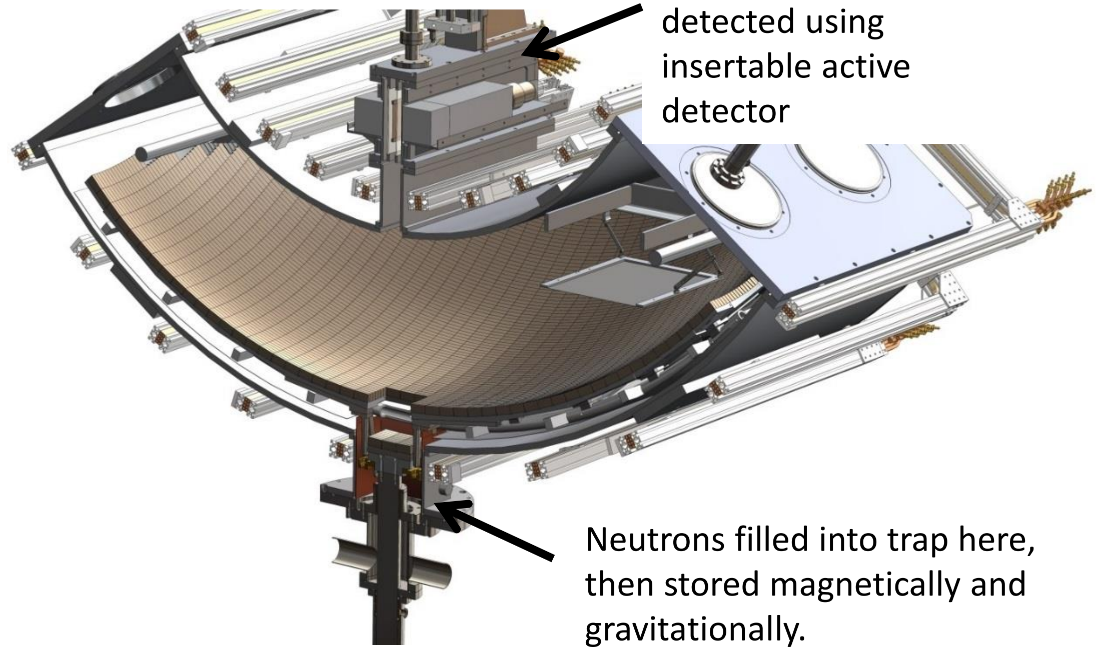


Feasibility Study for a Neutron Lifetime Experiment

The UCNτ experiment testbed is operational and acquiring data to study systematic effects.



Cubic meter trap stores tens of thousands of neutrons per fill, allowing rapid study of small effects.



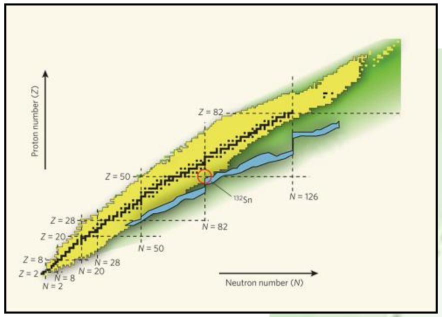
Key features of experiment:

1) Magnetic bottle has storage time much greater than free neutron lifetime, rapid phase space mixing
2) Rapid internal neutron detection scheme counts surviving neutrons with constant efficiency
3) No absolute counting efficiencies needed: only relative neutron counting

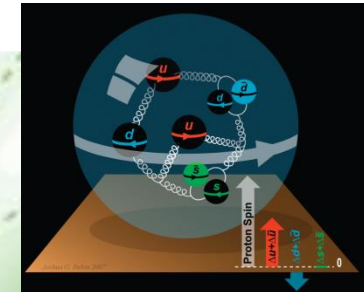
Progress in 2015-2016 LANSCE run cycle: commissioned an active in situ detector; performed intensive studies of neutron phase space evolution, superbarrier UCN removal ("cleaning"), normalization, and detector efficiency effects.

Although significant, the NP investment in Fundamental Symmetries is modest to date, and to an extent the planned new structure for managing this scope is reorganization at HQ rather than revolution in the balance among NP investments

JLab: Medium Energy Nuclear Science and Its Broader Impacts

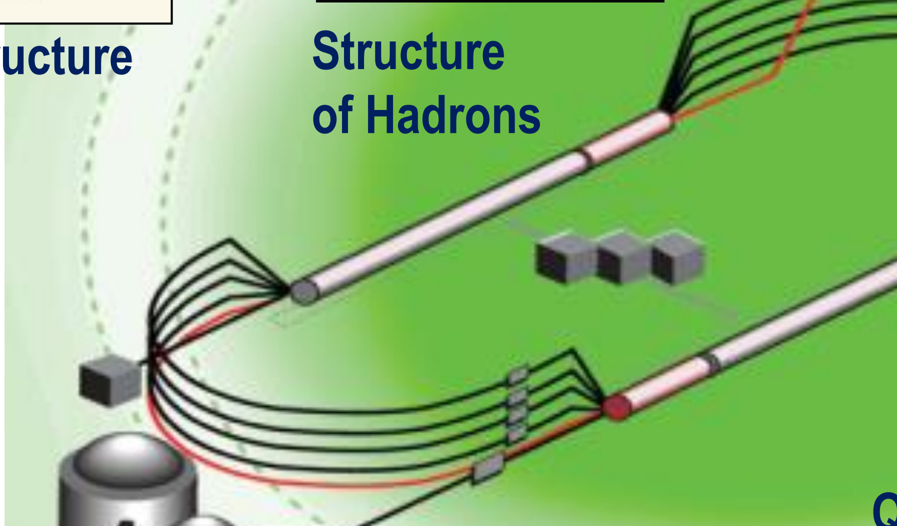


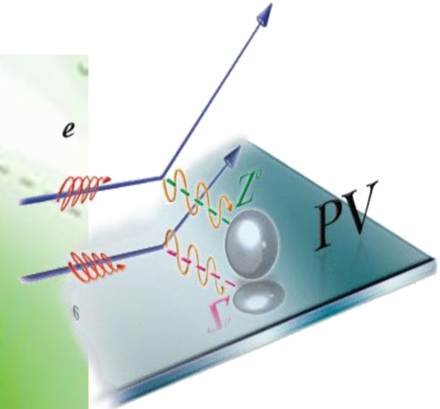
Nuclear Structure



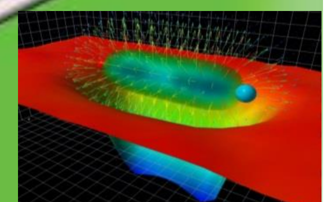
Structure of Hadrons

Medical Imaging



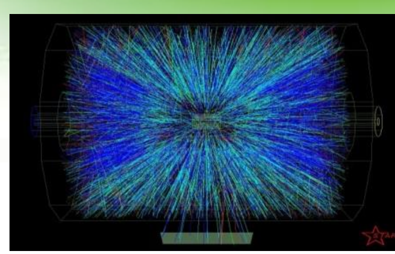


Fundamental Forces & Symmetries



Quark Confinement

Accelerator S&T

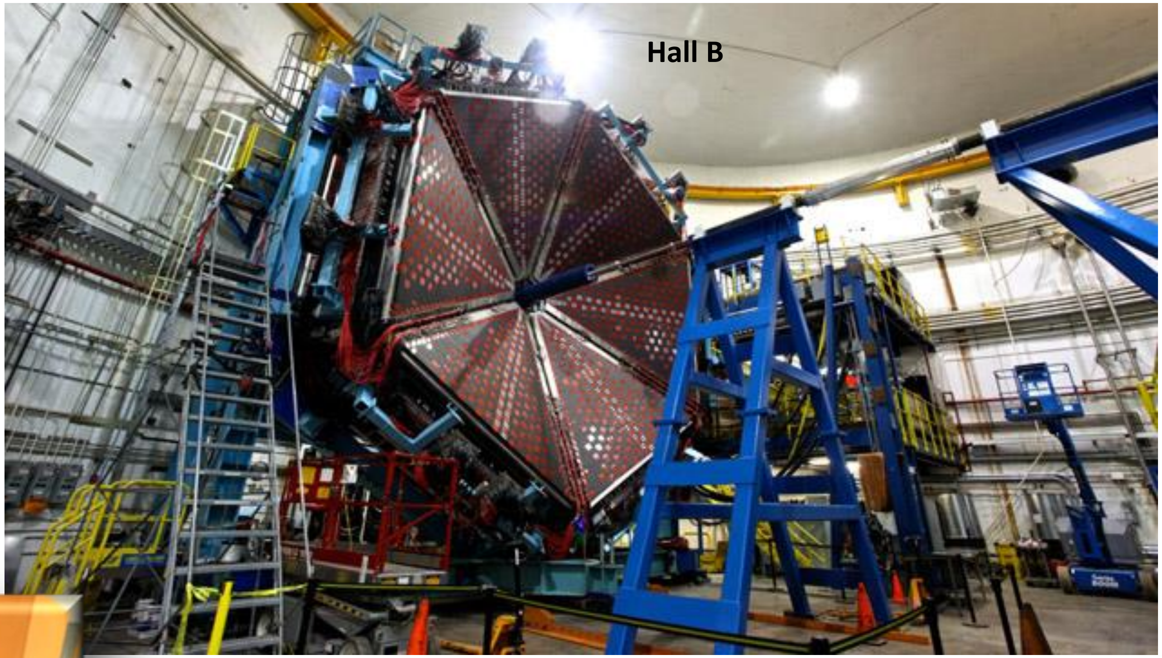


Hadrons from QGP

Theory and Computation

The 12 GeV CEBAF Upgrade at TJNAF is ~ 98% Complete

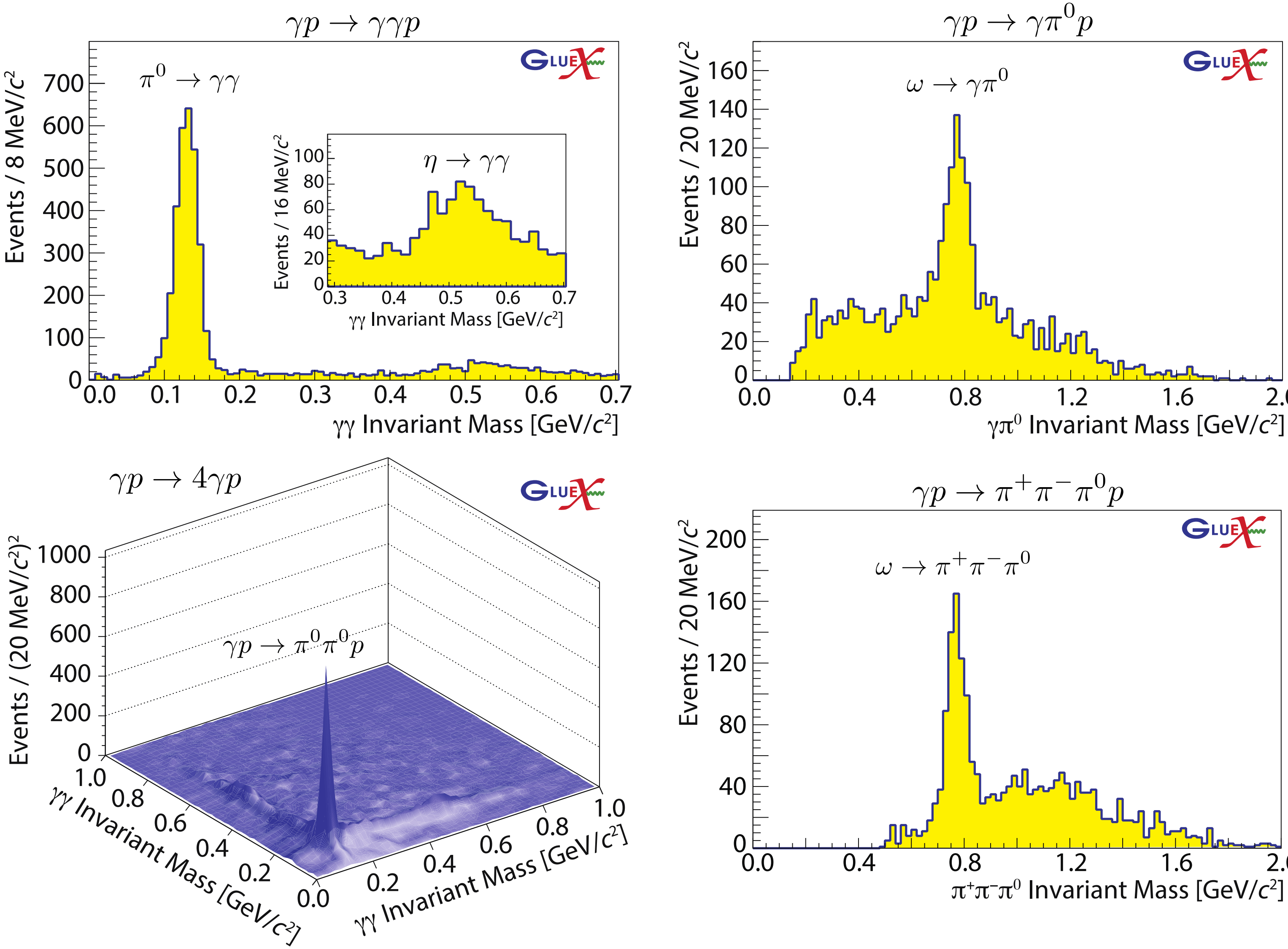
Project completion (CD-4B) is planned by the end of FY 2017



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.

First Results Demonstrating the Promise of GLUEX

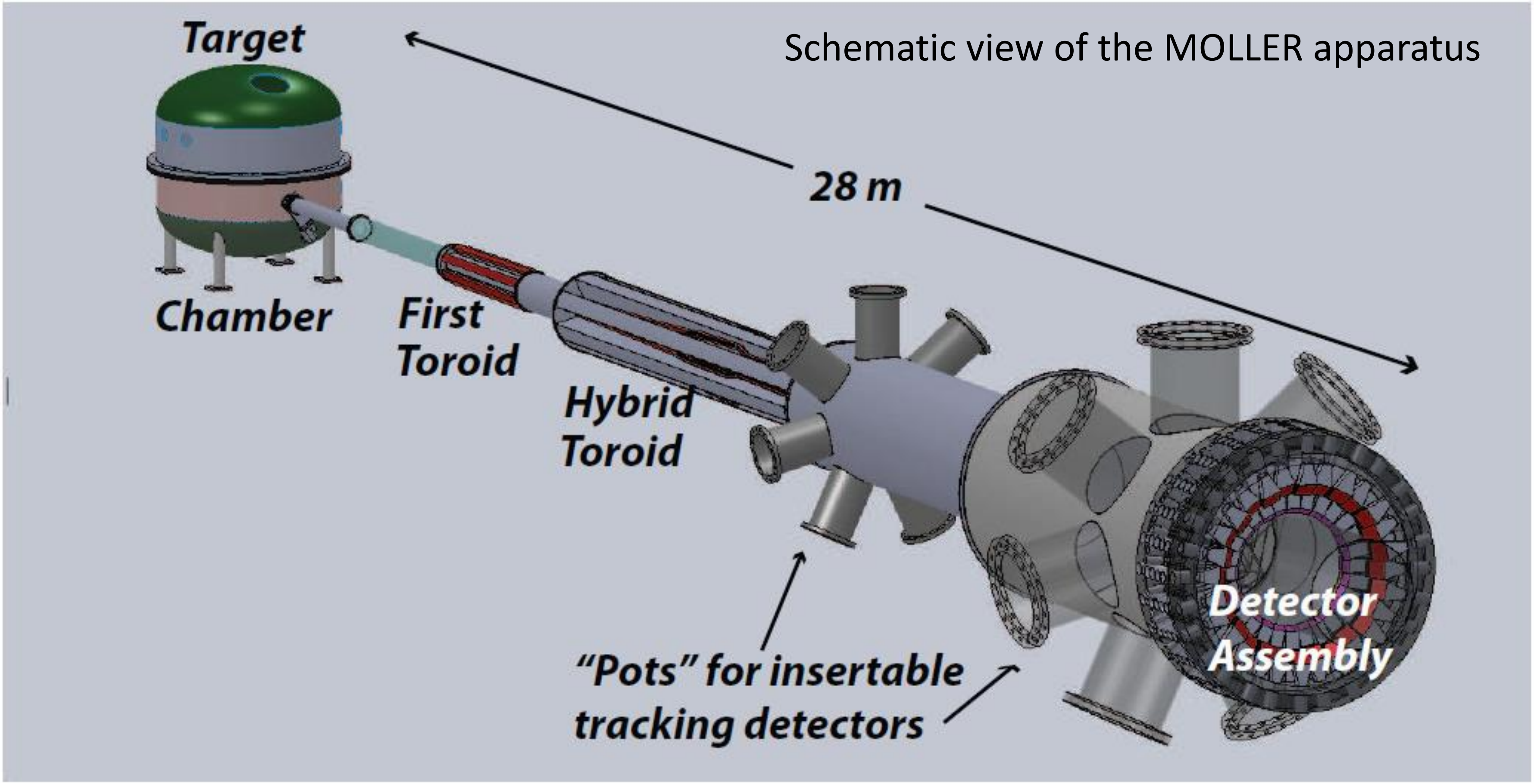


JLab: 21st Century Science Questions

- What is the role of gluonic excitations in the spectroscopy of light mesons? Can these excitations elucidate the origin of quark confinement?
- Where is the missing spin in the nucleon? Is there a significant contribution from valence quark orbital angular momentum?
- Can we reveal a novel landscape of nucleon substructure through measurements of new multidimensional distribution functions?
- What is the relation between short-range N-N correlations and the partonic structure of nuclei?
- Can we discover evidence for physics beyond the standard model of particle physics?

The Office of Science is very much looking forward to the restart of the science program in the 12 GeV era.

Looking to the future: MOLLER at JLAB



MOLLER had a successful science review. NP working to take the next step to continue progress

Overview of SoLID

The **So**lenoidal **L**arge **I**ntensity **D**evice

- SoLID will full exploit the JLab 12 GeV Upgrade

SoLID has a Large Acceptance Detector and Can Handle High Luminosity (10^{37}-10^{39})

It takes advantage of the latest developments in detectors and data acquisition to:

- Reach ultimate precision for SIDIS (TMDs), providing three-dimensional imaging of nucleon in momentum space
- Study PVDIS in high-*x* region providing sensitivity to new physics at 10-20 TeV, and QCD
- Measure threshold J/ψ, probing strong color field in the nucleon, trace anomaly

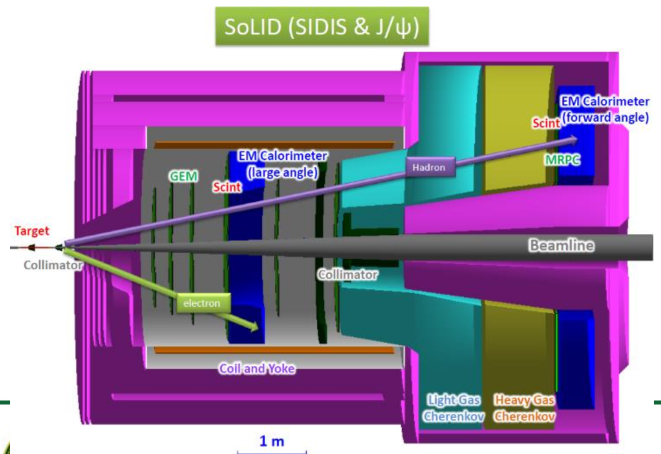
- 5 highly rated experiments have been approved

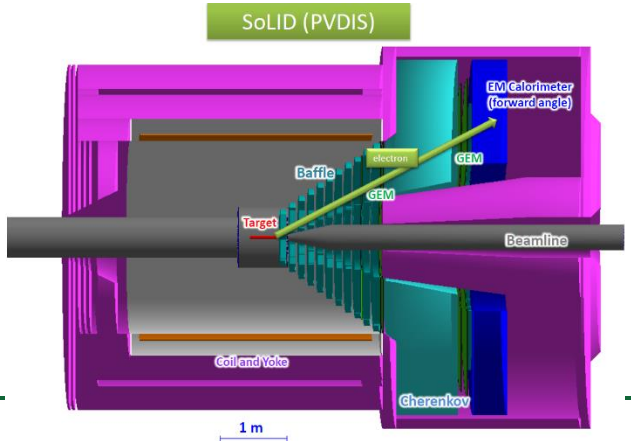
  Three SIDIS experiments, one PVDIS, one J/ψ production

  Run group experiments: di-hadron, Inclusive-SSA, and much more …

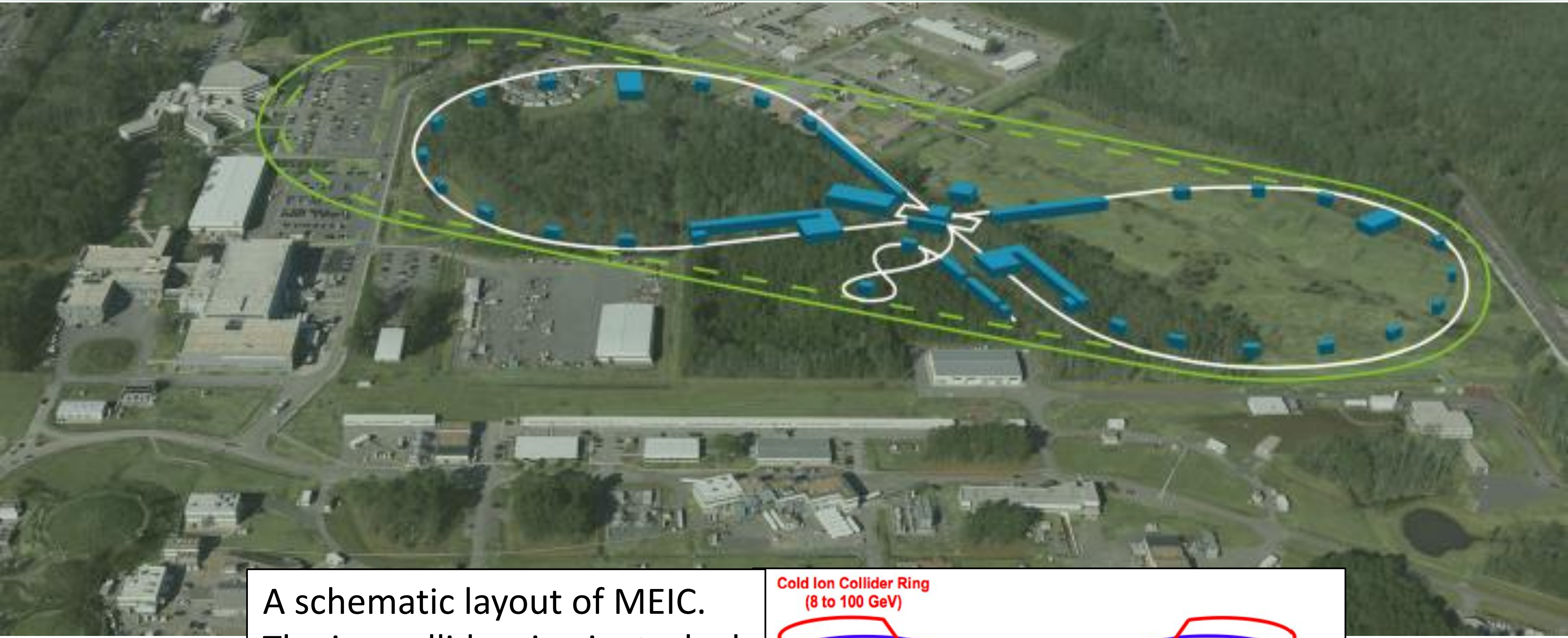
- A strong collaboration exists (250+ collaborators from 70+ institutes, 13 countries)

  Significant international (Chinese) contributions and strong theoretical support

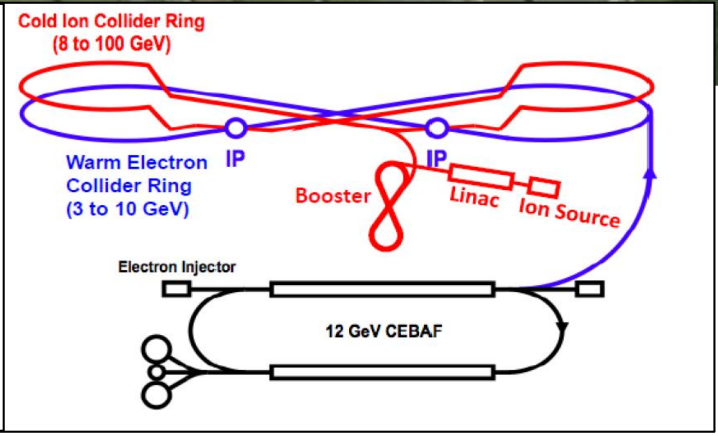




A Possible Future MEIC at JLAB

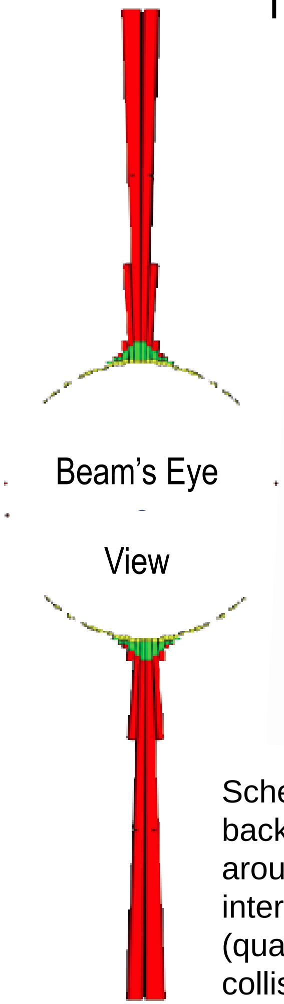


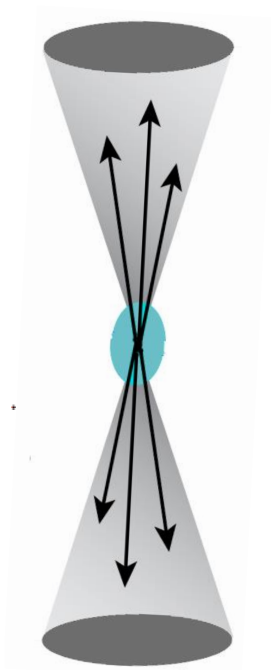
A schematic layout of MEIC. The ion collider ring is stacked vertically above the electron collider ring and take a vertical excursion to the plane of the electron ring for a horizontal crossing



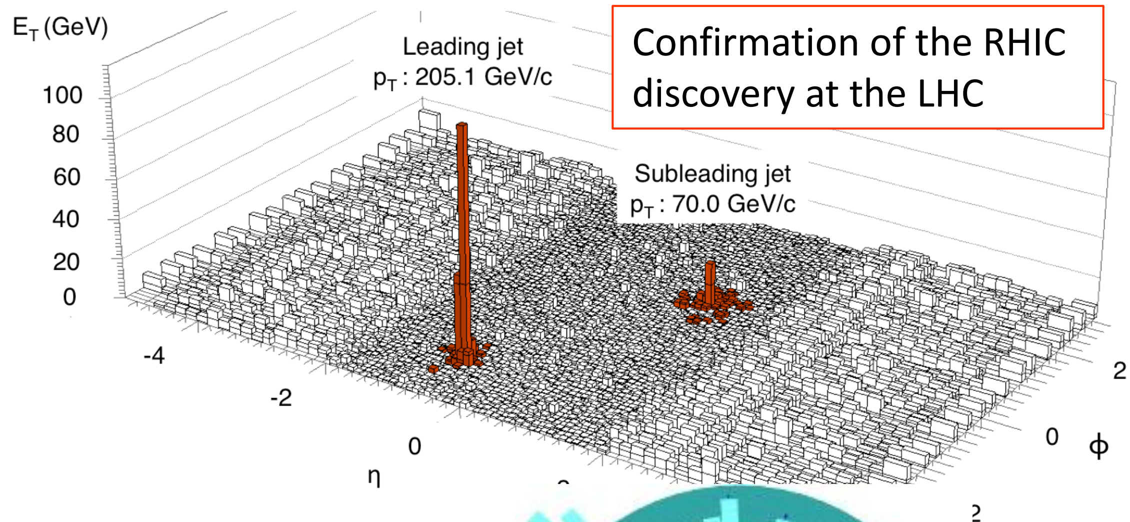
A Brief Reprise of The RHIC Discovery: A Strongly Interacting, Perfect Liquid of Quark and Gluons

The measurement of jets yields a signature discovery: “Jet Quenching”



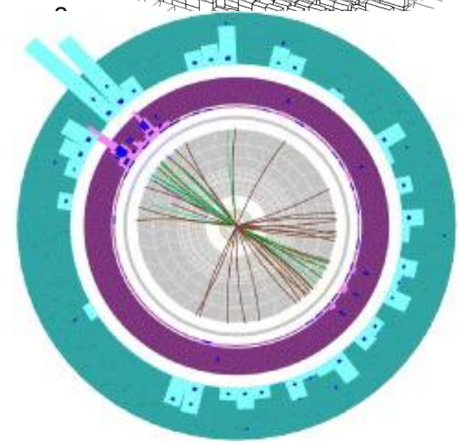


Schematic of expected symmetric back-to-back energy flow (“jets”) around the beam direction from the interaction of two energetic partons (quarks, gluons) in proton – proton collisions



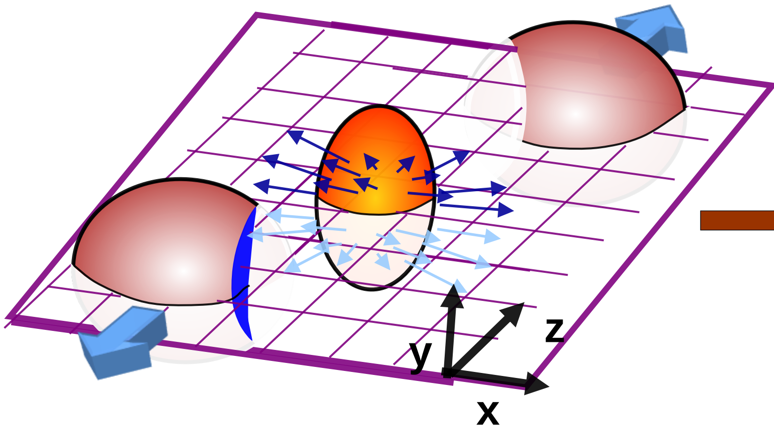
Confirmation of the RHIC discovery at the LHC

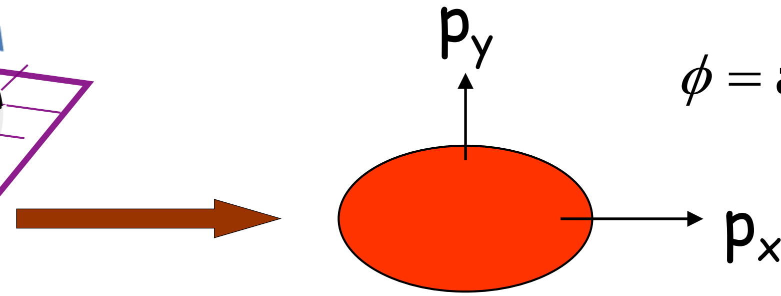
Asymmetric non back-to-back (jet) energy flow around the beam direction from the interaction of two energetic partons (quarks, gluons) in relativistic nucleus-nucleus collisions



The 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.

The Other Signature RHIC Discovery: Collective Motion & "Elliptic Flow"





$$\phi = \operatorname{atan}\frac{p_y}{p_x}$$

Elliptic flow establishes there is strongly interacting matter at t ~ 0

$$\varepsilon = \frac{\langle y^2 \rangle - \langle x^2 \rangle}{\langle y^2 \rangle + \langle x^2 \rangle}$$

Initial coordinate-space anisotropy

$$v_2 = \left\langle \frac{p_x^{\,2} - p_y^{\,2}}{p_x^{\,2} + p_y^{\,2}} \right\rangle$$

Final momentum-space anisotropy

$$\frac{dN}{d\phi} \propto 1 + 2v_2 \cos[2(\phi - \Psi_R)] + 2v_4 \cos[4(\phi - \Psi_R)] + \ldots$$

Elliptic term

Anisotropy self-quenches, so v_2 is sensitive to early times

Key Science Drivers Yet to Be Answered

- How does the perfect liquid behavior emerge from the short-distance degrees of freedom?
- What conditions produce the most nearly perfect liquid behavior?
- Is there a critical end point and change to a 1st order phase transition in the QCD phase diagram?
- Which mechanisms or conditions drive early thermalization in nuclear collisions?
- Can the effects of quantum anomalies be detected in the final state?

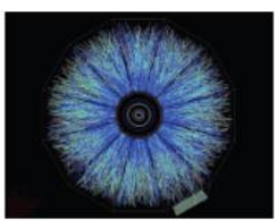
An Intriguing New Focus: Verification of the Chiral Magnetic Effect

A Unique Feature of RHIC Events: High Instantaneous Magnetic Fields

Comparison of magnetic fields

The Earths magnetic field	0.6 Gauss
A common, hand-held magnet	100 Gauss
The strongest steady magnetic fields achieved so far in the laboratory	4.5 x 10^5 Gauss
The strongest man-made fields ever achieved, if only briefly	10^7 Gauss
Typical surface, polar magnetic fields of radio pulsars	10^{13} Gauss
Surface field of Magnetars	10^{15} Gauss

http://solomon.as.utexas.edu/~duncan/magnetar.html



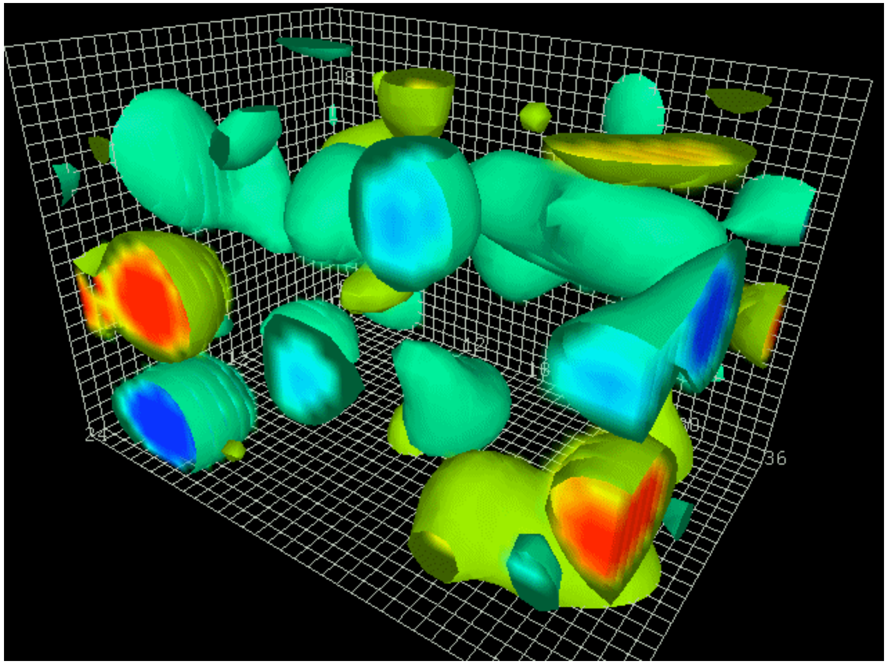
Heavy ion collisions: the strongest magnetic field ever achieved in the laboratory

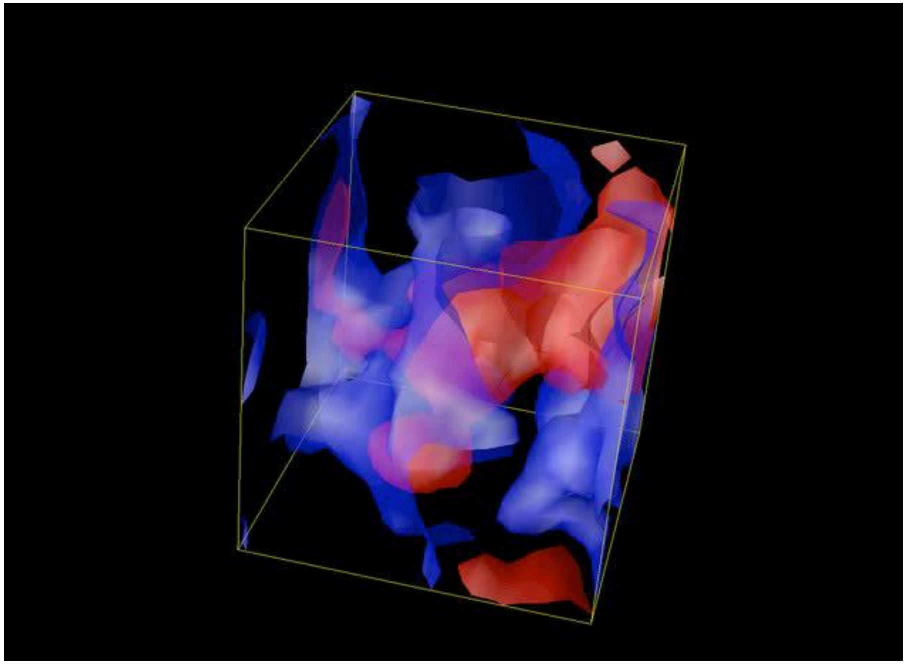
Off central Gold-Gold Collisions at 100 GeV per nucleon

$$eB(\tau = 0.2\,\mathrm{fm}) = 10^3 \sim 10^4\ \mathrm{MeV}^2 \sim 10^{17}\,\mathrm{Gauss}$$

The Next Ingredient

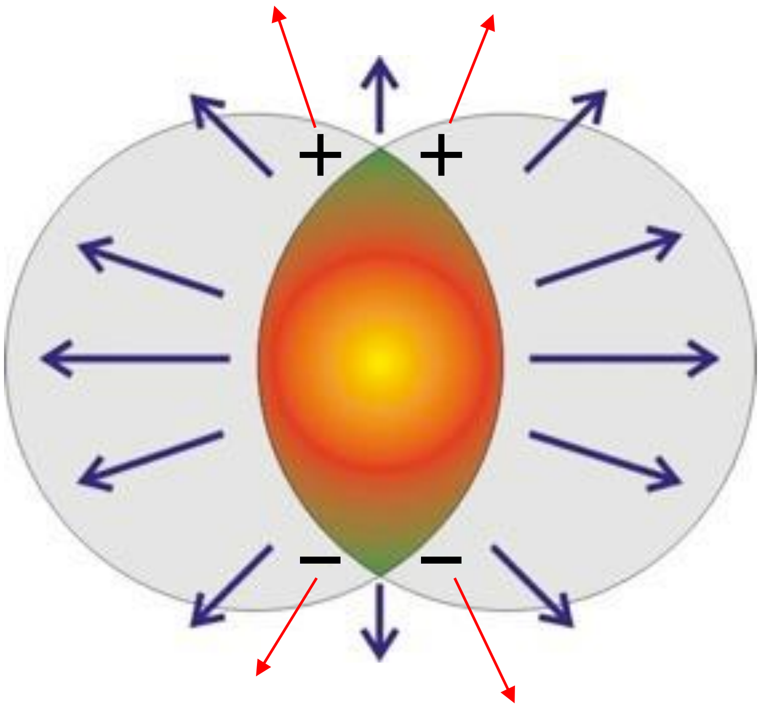
Topological Number Fluctuations Which Occur in the QCD Vacuum Continuously



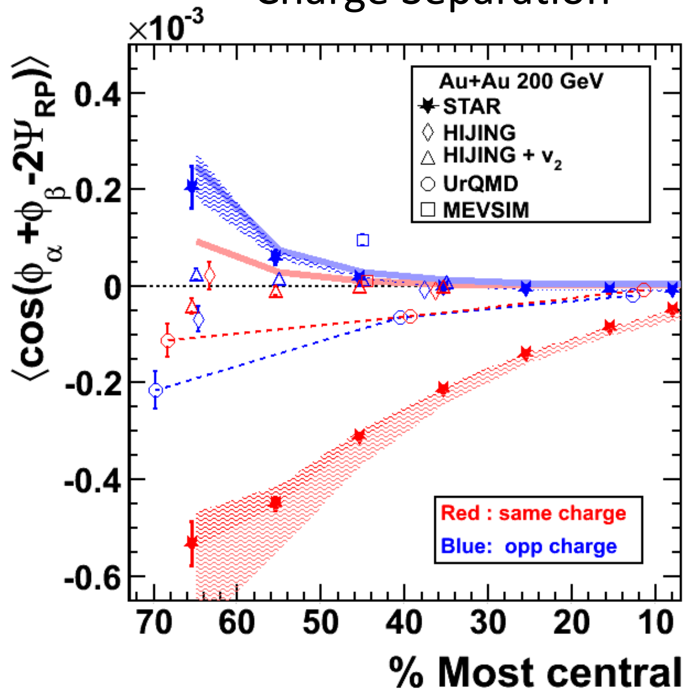


- Topological gluonic configurations produce asymmetry in right- vs left-handed quarks

The Response of a Chirally Imbalanced System to an External Magnetic Field?



Charge Separation



Other experimental observables studied,

- in-plane (left/right) vs. out-of-plane (up/down) charge correlations
- Beam energy dependence
- System size dependence

All observables studied to date are consistent with the CME Interpretation
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

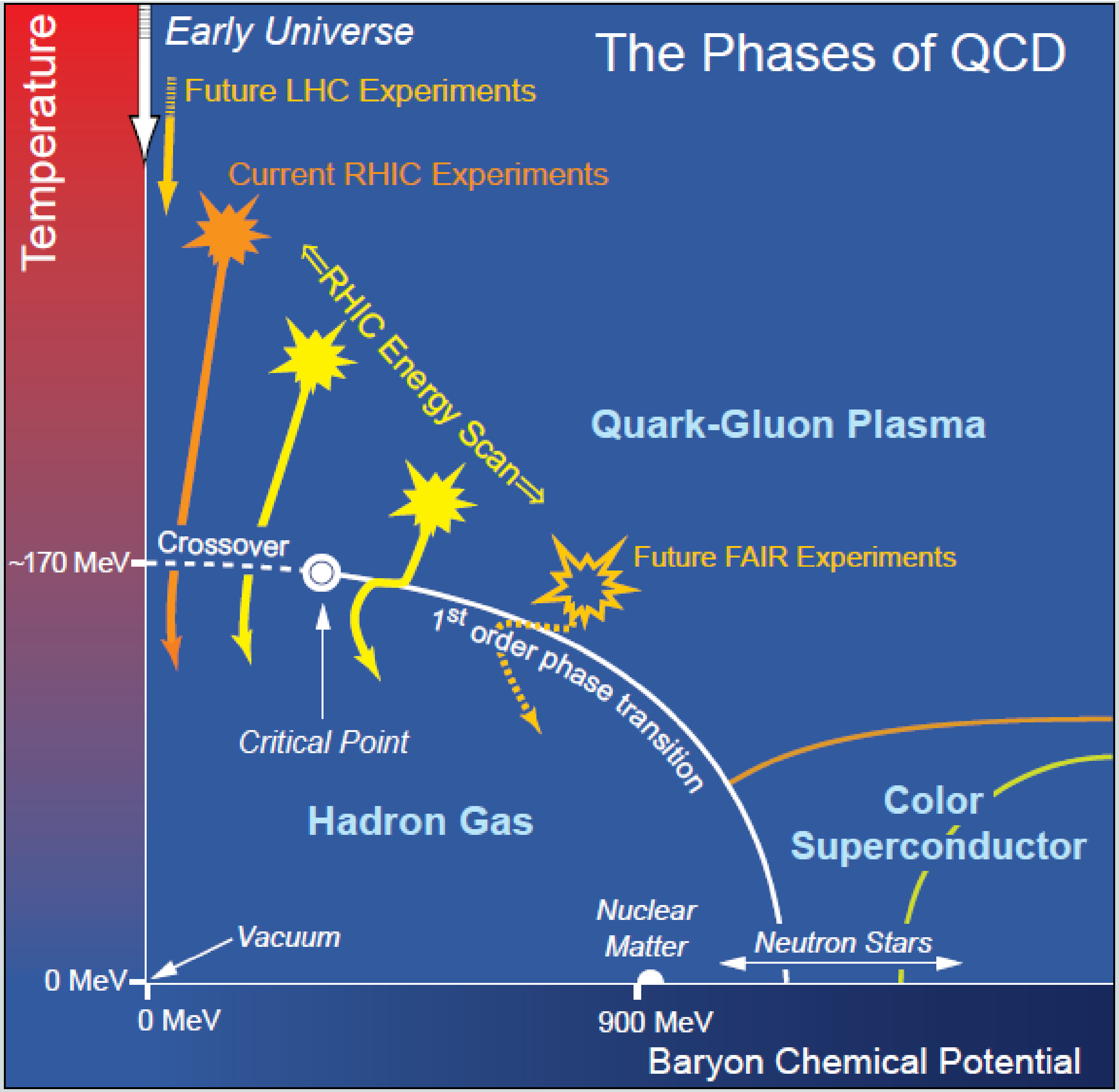
The QCD Critical Point Search: A Main Focus of RHIC Running in FY19-20

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.

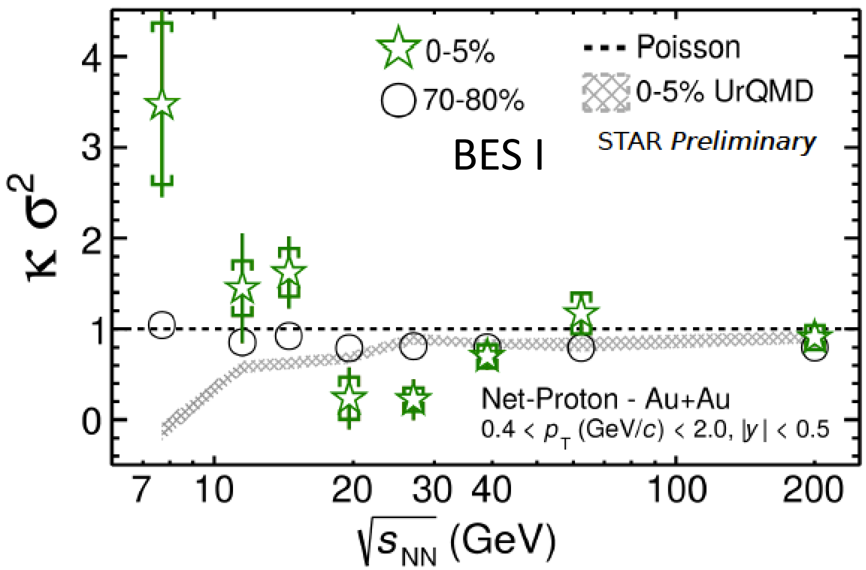
Experimentally verifying the location of fundamental QCD “landmarks” is central to a quantitative understanding of the nuclear matter phase diagram. Lattice QCD indicates that the Critical Point is in the range of temperatures and chemical potentials accessible with RHIC. The approach to the Critical 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



Upgrading the STAR Inner TPC Sectors is Critical for This Discovery

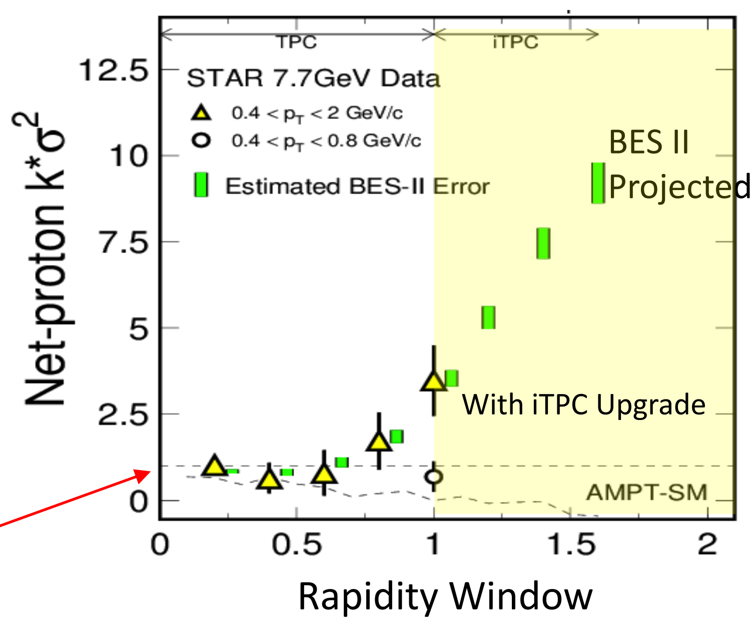


A primary signature of the Critical Point will be non-Poissonian scaled kurtosis (baryon fluctuations)

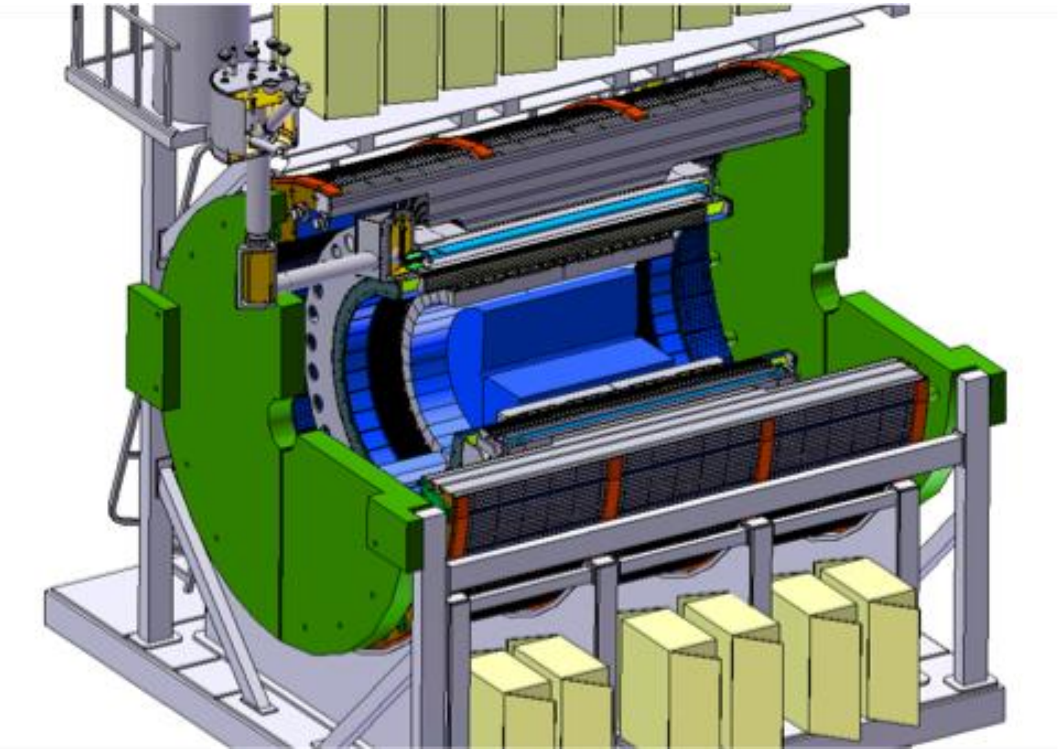
Results from the first survey run appear tantalizing, but the statistics do not allow a conclusion. Fluctuations consistent with Poissonian behavior fall along the line at unity

The conjectured sensitivity to this observable improves dramatically at forward pseudo-rapidity (yellow shaded region at right) for which the inner TPC Upgrade is essential

Poissonian Reference



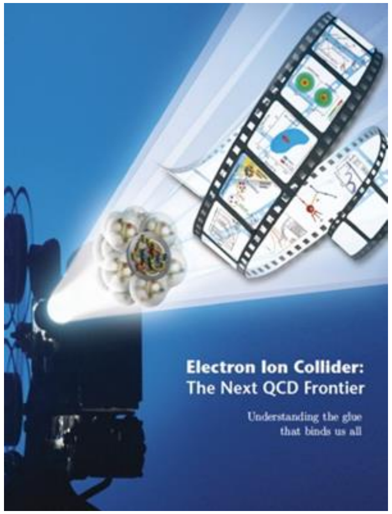
The Physics Thrusts of sPHENIX



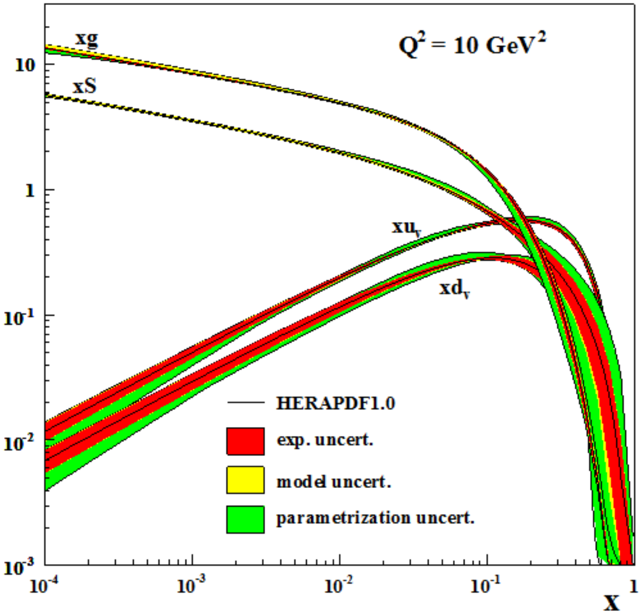
The main scientific thrusts are

- 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.

The Further Future of QCD: Understanding the Glue That Binds Us All



- 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.

Next Formal Step on the EIC

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 was requested from the Department of Energy.

<u>Panel Being Selected</u>

<u>First Meeting Later This Year</u>

Nuclear Theory

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

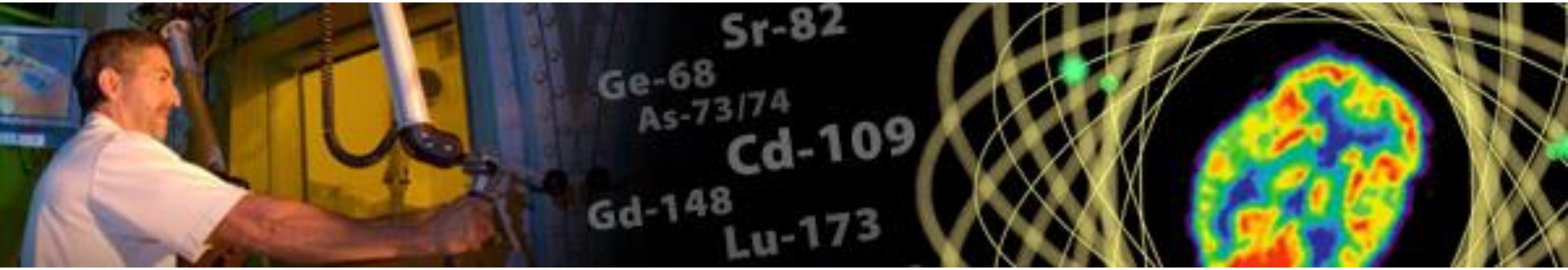
A strong Nuclear Theory effort:

- 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 successful new approach for NP—Theory Topical Collaborations are fixed-term, multi-institution collaborations established to investigate a specific topic

- "A new direction to enhance the research effort by bundling scientific strength and expertise located at different institutions to reach a broader scientific goal for the benefit of the entire nuclear science community… an extremely promising approach for funding programmatic and specific science goal oriented research efforts."

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

Status and Outlook

- The RHIC and CEBAF programs are both unique and at the “top of their game” with compelling “must-do” science in progress or about to start.
- Long term, an electron-ion collider is envisioned to be the facility which provides exciting opportunities fort the entire experimental QCD research community. An important challenge is charting and being able to follow a course to this future which realizes expected scientific return on existing investment and does not leave important science discoveries “on the table” –forever perhaps.
- A very high priority for the NP community is maintaining 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
  - A concomitant challenge will be ensuring inclusiveness and fairness for all demonstration efforts in progress and completing the down-select in a timely way so as not to endanger US leadership in this science.
- A second 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.