A NEW ERA OF DISCOVERY

THE 2023 LONG RANGE PLAN FOR NUCLEAR SCIENCE

Nuclear Science Community Briefing

October 6, 2023

Gail Dodge, NSAC Chair

The Charge from DOE and NSF

U.S. Department of Energy
and the
National Science Foundation

July 11, 2022

Professor Gail Dodge
Chair, DOE/NSF Nuclear Science Advisory Committee
College of Sciences
Old Dominion University
4600 Elkhorn Avenue
Norfolk, Virginia 23529

Dear Professor Dodge:

This letter requests that the Department of Energy (DOE)/National Science Foundation (NSF) Nuclear Science Advisory Committee (NSAC) conduct a new study of the opportunities and priorities for United States nuclear physics research and recommend a long-range plan (LRP) that will provide a framework for coordinated advancement of the Nation's nuclear science research programs over the next decade.

The new NSAC LRP should articulate the scope and the scientific challenges of nuclear physics today, what progress has been made since the last LRP, and the impacts of these accomplishments both within and outside the field. It should identify and prioritize the most compelling scientific opportunities for the U.S. nuclear physics program to pursue over the next decade (fiscal year (FY) 2023-2032) and articulate its potential scientific impact. Further, a nationally coordinated strategy for the use of existing and planned capabilities, both domestic and international, and the rationale for new investments should be articulated. To be most helpful, the LRP should indicate what resources and funding levels would be required, including construction of new facilities, mid-scale instrumentation, and Major Items of Equipment, to maintain a world-leadership position in nuclear physics research. The LRP should also describe the potential impacts and priorities under constant level of effort budgets, 2 percent growth per year using the FY 2022 enacted funding level as a reference.

The extent, benefits, impacts, and opportunities of international coordination and collaborations afforded by current and planned major facilities and experiments in the United States (U.S.) and other countries, and of interagency coordination and collaboration in crosscutting scientific opportunities identified in studies involving different scientific disciplines should be specifically addressed and articulated in the report. Further, the scientific impacts of synergies with neighboring research disciplines and further opportunities for mutually beneficial interactions with outside disciplines should be discussed. The document should also articulate how efforts to promote and sustain a diverse, equitable, and inclusive nuclear science workforce will be fully integrated into every aspect of the vision for the future of U.S. nuclear science.

In the development of previous LRPs, the Division of Nuclear Physics of the American Physical Society (DNP/APS) was instrumental in obtaining broad community input by organizing town meetings of different nuclear physics sub-disciplines. The Division of Nuclear Chemistry and Technology of the American Chemical Society (NUCL/ACS) was also involved. We encourage NSAC to exploit this method of obtaining widespread input again and to further engage the DNP/APS and NUCL/ACS in laying out the broader issues of contributions of nuclear science research to society.

Please submit your initial report to DOE and NSF by October 2023. The agencies very much appreciate NSAC's willingness to undertake this task. NSAC's previous LRPs have played a critical role in shaping the Nation's nuclear science research efforts. Based on NSAC's laudable efforts in the past, we look forward to a new plan that can be used to chart a vital and forefront scientific program into the next decade.

Sincerely,

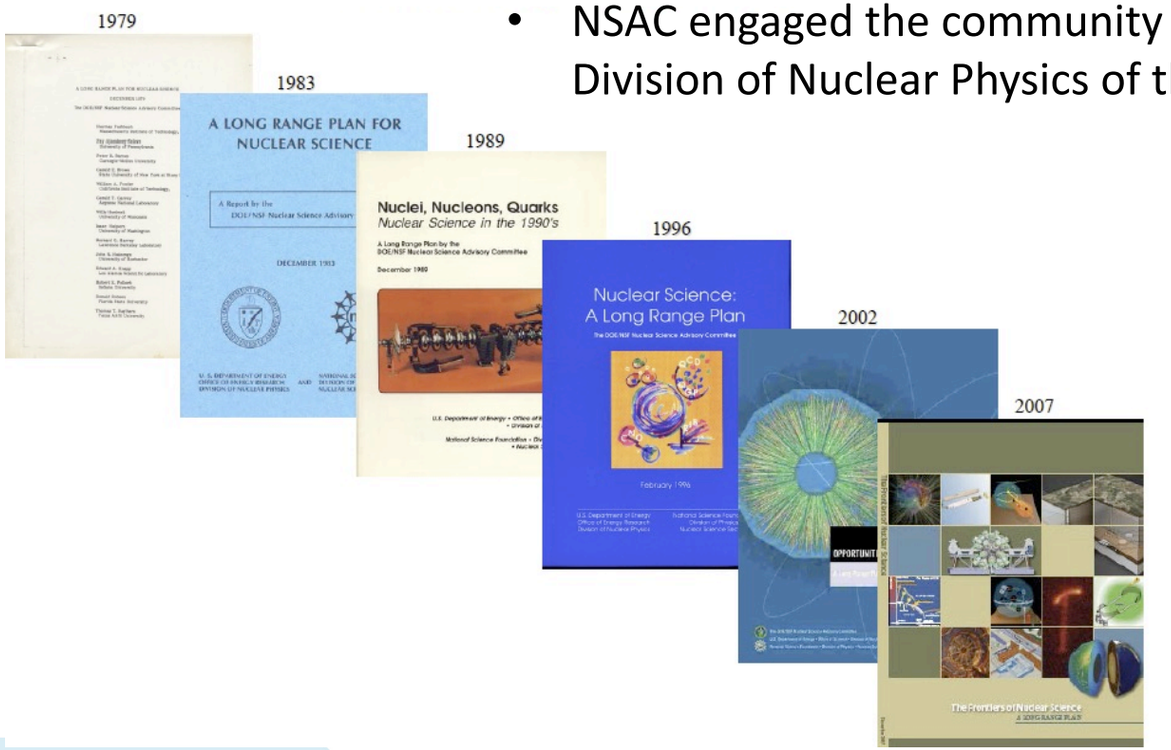
Asmeret Asefaw Berhe
Director
Office of Science

Sean L. Jones
Assistant Director
Directorate for Mathematical
and Physical Sciences
National Science Foundation

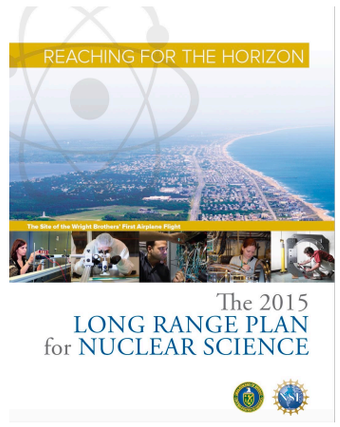
Successful History of Long Range Planning in Nuclear Science

Since 1979 the Department of Energy Office of Science and the National Science Foundation periodically have charged the Nuclear Science Advisory Committee, NSAC, to provide a framework for coordinated advancement of the Nation's nuclear science research program.

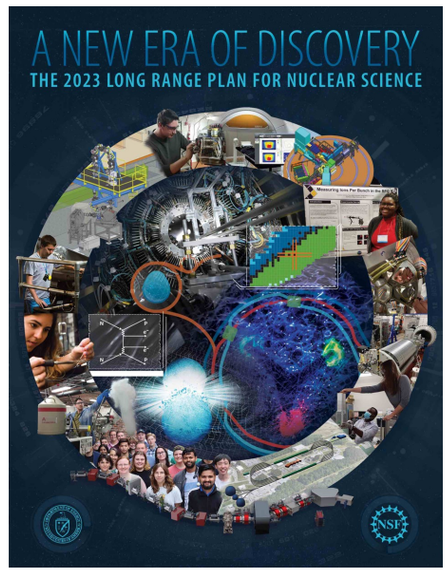
- A consistent, strategic plan for investments was developed every 5 – 7 years
- NSAC engaged the community though town meetings organized by the Division of Nuclear Physics of the American Physical Society



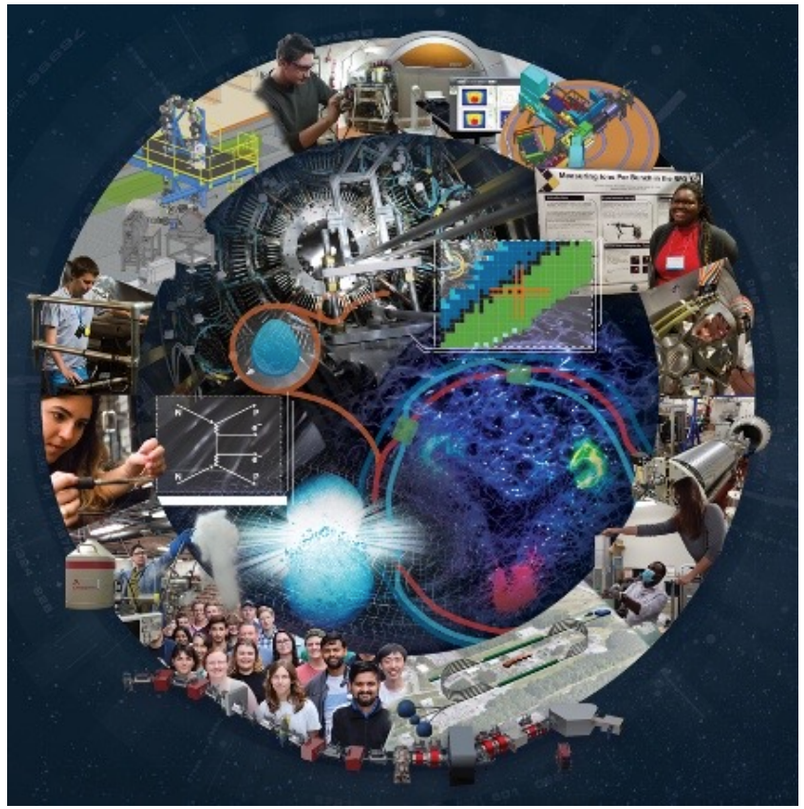
2015



2023

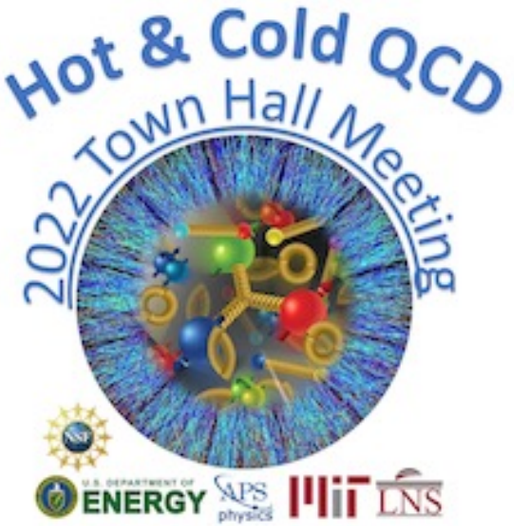


The Process

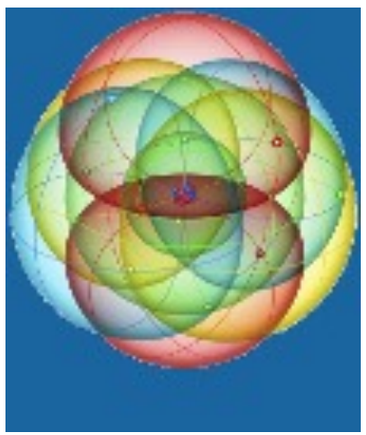


APS/DNP organized town meetings

2022 Town Meeting on Hot & Cold QCD
Sept. 23 – 25, 2022
Massachusetts Institute of Technology



NSAC Long Range Plan Town Hall Meeting on Nuclear Structure, Reactions and Astrophysics
Nov 14 – 16, 2022
Argonne National Laboratory



Fundamental Symmetries, Neutrons, and Neutrinos Town Meeting
Dec 13 – 15, 2022
University of North Carolina – Chapel Hill

Thank you to the conveners of these town meetings!!

Whitepapers

Each town meeting as well as other collaborations or gatherings produced white papers.

Available on the open website: *NuclearScienceFuture.org*

These documents were invaluable input to the writing committee and serve as excellent summaries of the accomplishments in the field and opportunities for the future.

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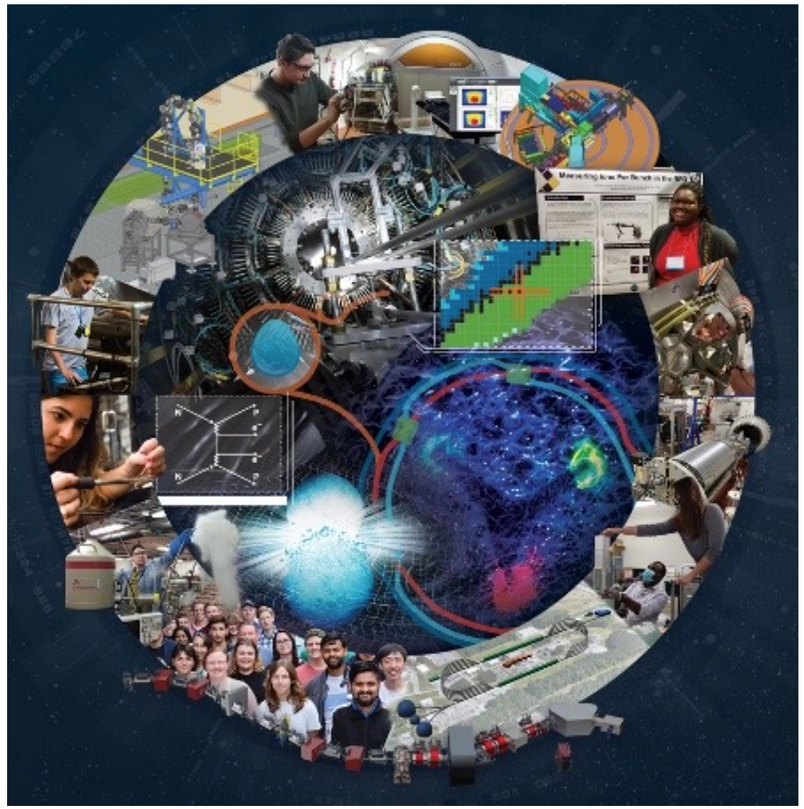
- Fundamental Symmetries (Brent VanDevender)
- Nuclear Structure & Nuclear Astrophysics (Ani Aprahamian)
- Workforce (Shelly Lesher)
- Applications (Calvin Howell and Mike Carpenter)
- Theory (Filomena Nunes)
- Crosscutting/interdisciplinary (Ian Cloët)
- Impact and synergies with other fields (Jorge Piekarewicz)
- Facilities (Haiyan Gao)
- International Context (Krishna Kumar)
- Budget (Sherry Yennello)

The Recommendations



RECOMMENDATION 1

The highest priority of the nuclear science community is to capitalize on the extraordinary opportunities for scientific discovery made possible by the substantial and sustained investments of the United States. We must draw on the talents of all in the nation to achieve this goal.

RECOMMENDATION 1 requires

- Increasing the research budget that advances the science program through support of theoretical and experimental research across the country, thereby expanding discovery potential, technological innovation, and workforce development to the benefit of society.
- Continuing effective operation of the national user facilities ATLAS, CEBAF, and FRIB, and completing the RHIC science program, pushing the frontiers of human knowledge.
- Raising the compensation of graduate researchers to levels commensurate with their cost of living—without contraction of the workforce—lowering barriers and expanding opportunities in STEM for all, and so boosting national competitiveness.
- Expanding policy and resources to ensure a safe and respectful environment for everyone, realizing the full potential of the US nuclear workforce.

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RECOMMENDATIONS 2 and 3

Next, we reaffirm the exceptionally high priority of the following two investments in new capabilities for nuclear physics. The Electron–Ion Collider (EIC), to be built in the United States, will elucidate the origin of visible matter in the universe and significantly advance accelerator technology as the first new particle collider to be constructed since the LHC. Neutrinoless double beta decay experiments have the potential to dramatically change our understanding of the physical laws governing the universe.

RECOMMENDATION 2

As the highest priority for new experiment construction, we recommend that the United States lead an international consortium that will undertake a neutrinoless double beta decay campaign, featuring the expeditious construction of ton-scale experiments, using different isotopes and complementary techniques.

Neutrinoless Double Beta Decay ($0\nu\beta\beta$)

Observation of $0\nu\beta\beta$ would mean that the neutrino is its own antiparticle.

It would also mean that lepton number is not conserved.

It would mean that matter can be created and help explain why the universe has more matter than antimatter.

The rate of $0\nu\beta\beta$ has implications for neutrino masses.

Regular beta decay:

$n \rightarrow p + e^- + \bar{\nu}_e$

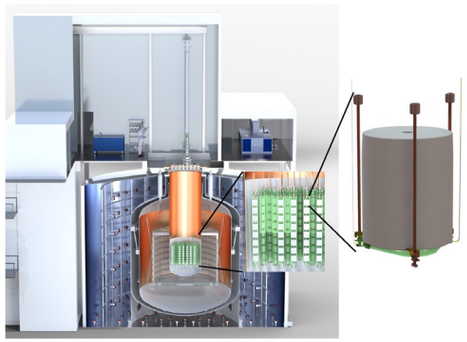
Double beta decay (DBD):

$2n \rightarrow 2p + 2e^- + 2\bar{\nu}_e$

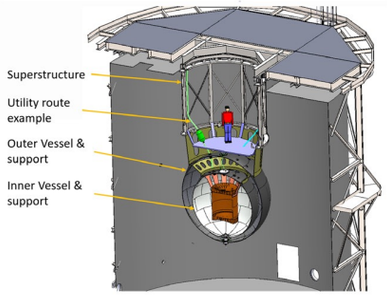
Neutrinoless DBD:

$2n \rightarrow 2p + 2e^-$

Major discovery potential!



LEGEND



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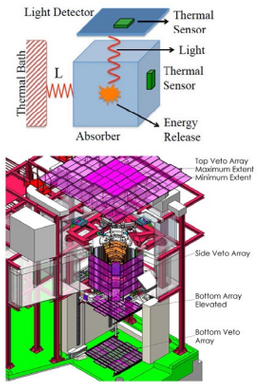
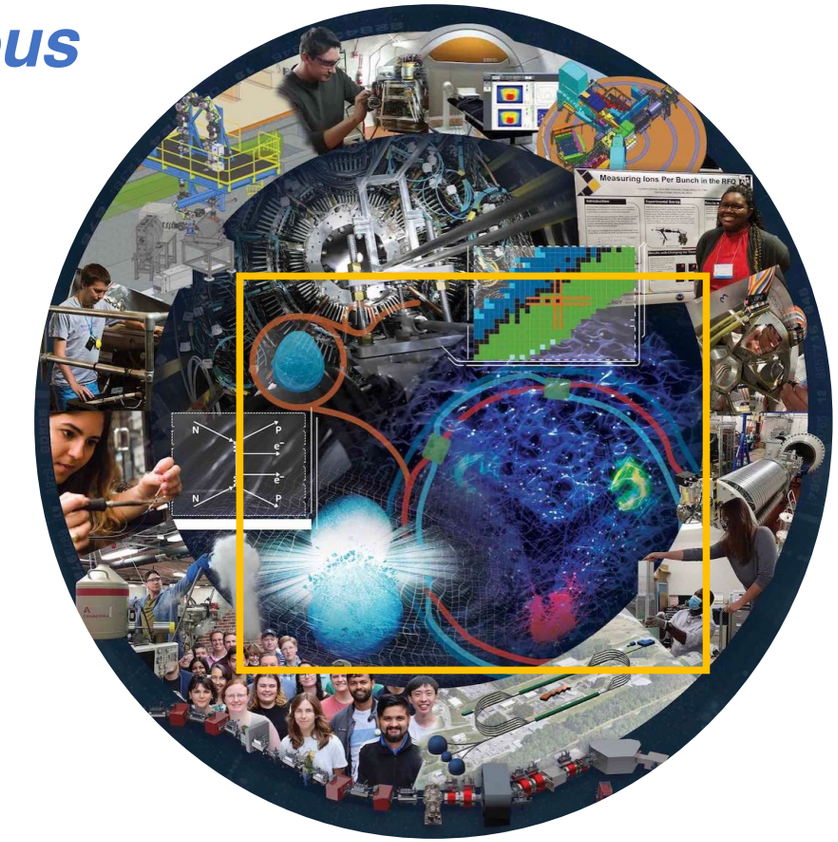


CUPID

RECOMMENDATION 3

We recommend the expeditious completion of the EIC as the highest priority for facility construction.



The Electron-Ion Collider

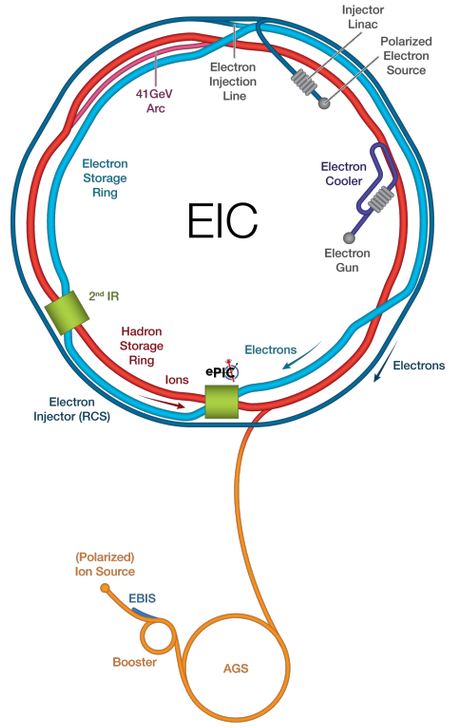
Polarized electrons colliding with polarized protons, polarized light ions, and heavy ions will allow us to study sea-quarks and gluons to understand:

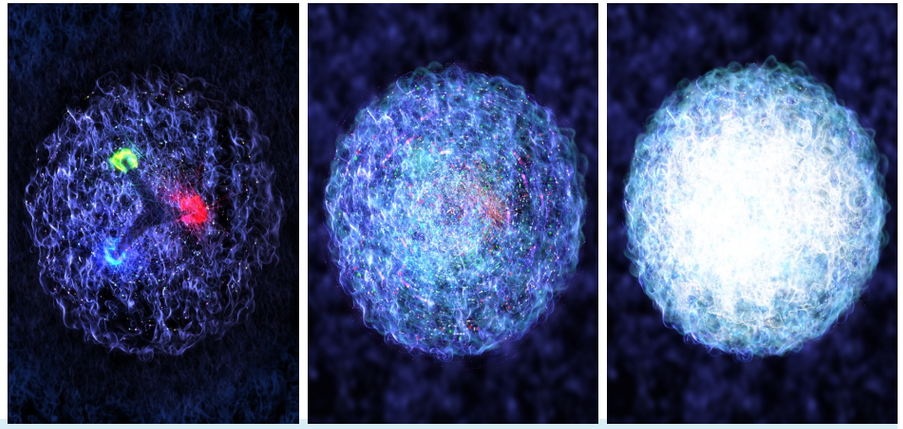
- mass and spin of the proton.
- spatial and momentum distribution of low-x partons
- Possible gluon saturation
- modifications of parton distribution functions when a nucleon is embedded in a nucleus
- hadron formation

The EIC is a partnership between BNL and Jefferson Lab.

Project is aiming for CD2/3 in 2025

ePIC detector design is advanced. Significant international support and participation (160+ institutions, 24 countries).





Major discovery potential!

RECOMMENDATION 4

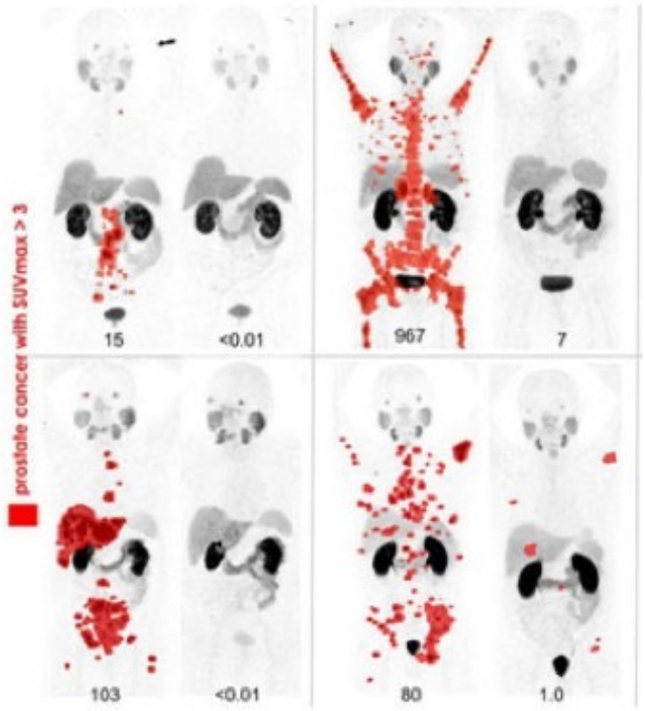
We recommend capitalizing on the unique ways in which nuclear physics can advance discovery science and applications for society by investing in additional projects and new strategic opportunities.

Strategic Opportunities

- Projects that lay the foundation for the discovery science of tomorrow
  - Examples: FRIB400, SoLID, LHC upgrades, EDM, ν mass measurements
- Detector and accelerator R&D
- Emerging technologies: computing and sensing
  - Quantum information science and technology
  - Artificial intelligence and machine learning
  - High performance computing
- Multidisciplinary centers
- Nuclear data

Benefits to the nation

- Synergy and impact on other fields, such as high energy physics, astrophysics and cosmology, accelerator science, atomic physics, condensed matter physics …
- Trained nuclear workforce, affects many fields, including nuclear security, isotope production for medical and other needs
- Applications: energy, health care, environmental issues, radiation hardening for electronics, improved particle detection for homeland security
- Development of computational techniques



PET images using gallium-68 before (left) and after (right) treatment of prostate cancer with lutetium-177-PSMA-617

Workforce

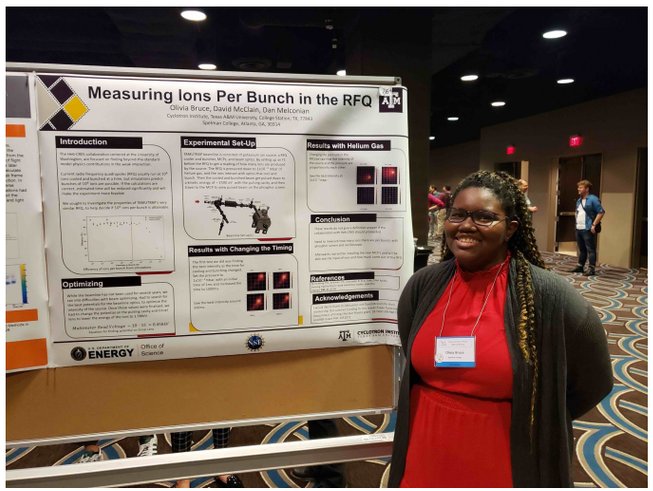
People are essential to accomplishing the goals in all areas of physics described in the Long Range Plan.

Programs such as the NSF REU and DOE SULI are essential to attracting talented students to nuclear science.

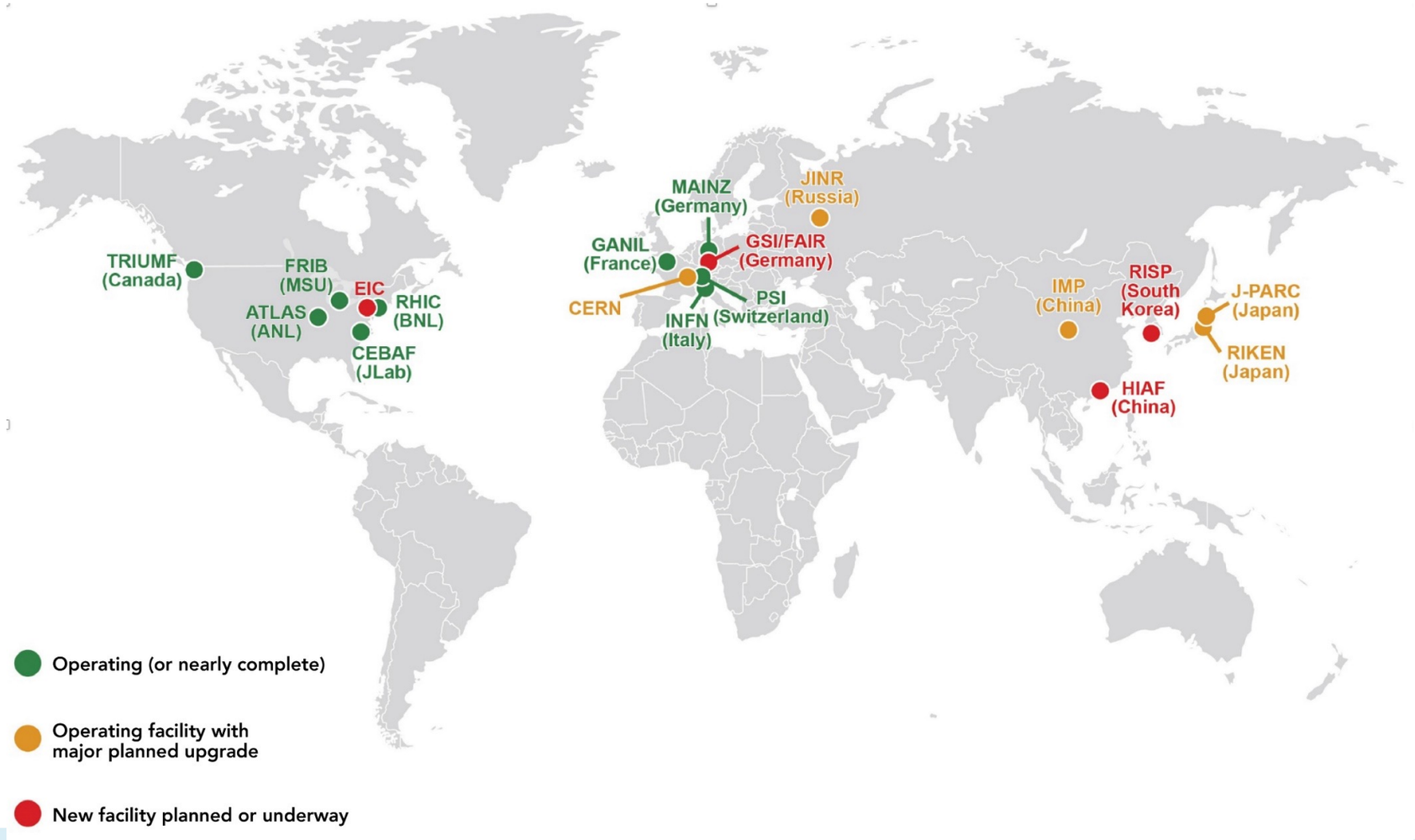
Central to our proposals is the necessity to reduce barriers to participation in nuclear science.

Our community is committed to establishing and maintaining an environment where all feel welcome and are treated with respect and dignity.

The training our students receive is very valuable in industry, national labs, and in critical areas of national need, such as nuclear nonproliferation and security



U.S. is currently in a position of leadership within an increasingly competitive nuclear physics landscape



Our vision for the future – maintaining world leadership in nuclear science

- The nuclear science community has come together to consider our progress since the last Long Range Plan and the compelling opportunities over the next ten years.
- We have articulated our priorities in the context of four budgetary scenarios – this required difficult choices.
- Maintaining our world-leading position in nuclear science requires investment – in people, in facilities, and in projects/experiments.
- Our science brings tremendous benefits to the nation – through the trained workforce, impact on other fields, advancing crosscutting technologies, and applications that benefit society.
- We are on the threshold of

A New Era of Discovery

Thank you!

The LRP Writing Committee

APS Division of Nuclear Physics

NSF and DOE leadership and staff

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