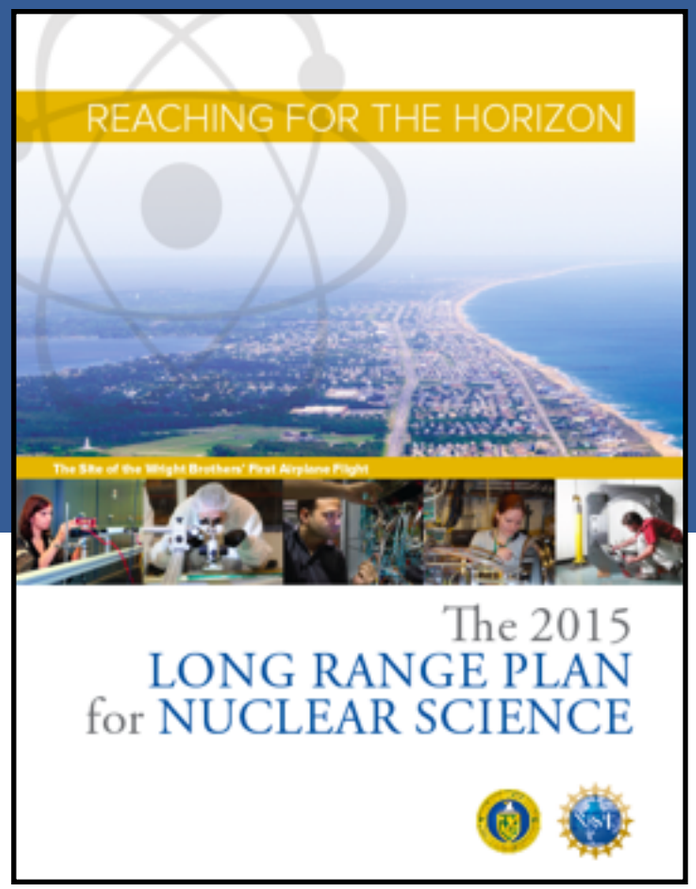
U.S. 0νββ-Decay Prospects & Process



U.S. ββ-Decay Support

2015 Long Range Plan for Nuclear Science

NSAC ββ-Decay (NLDBD) Sub-committee

DOE/NSF ββ-Decay Funding Process

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MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Overview of U.S. support of ββ-Decay

- **Support of ββ provided by two agencies:**
  - Department of Energy, Office of Science, Office of Nuclear Physics (DOE ONP).
  - National Science Foundation, Directorate of Mathematical and Physical Science, Nuclear Physics Program (NSF NP).

- **Experiments being supported**: CUORE, EXO, KamLAND Zen, MAJORANA DEMONSTRATOR, NEXT, SNO+, SuperNEMO.

- **A ton scale, next generation ββ-Decay experiments is the highest priority for new construction for the U.S. Nuclear Physics Program in the coming decade.**

U.S. Process towards a ton scale 0νββ

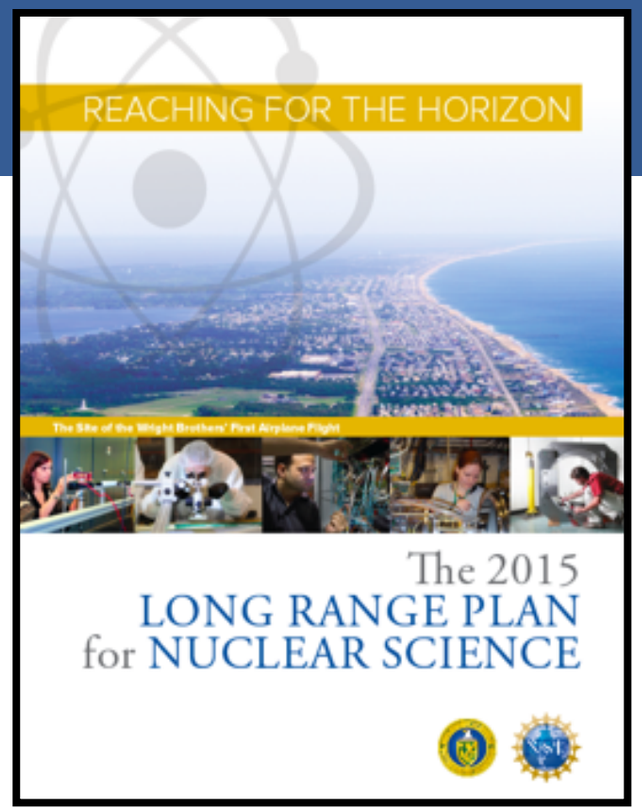
Nuclear Science Advisory Committee (NSAC) — committee of nuclear scientists that advises the Federal agencies involved in nuclear physics — the Department of Energy (DOE) Office of Nuclear Physics and the National Science Foundation (NSF)

Every 6-7 years, NSAC is charged with developing a **Long Range Plan (LRP)** for Nuclear Science. NSAC works with the American Physical Society (APS) Division of Nuclear Physics (DNP) to engage the community in developing the new plan.

Major new initiatives **must be endorsed** in the LRP in order to go forward. After 18 months of development, with extensive community involvement, the latest LRP was released on October 15, 2015

Link to the LRP: http://science.energy.gov/np/nsac/

NSAC 2015 Long Range Plan



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RECOMMENDATION II

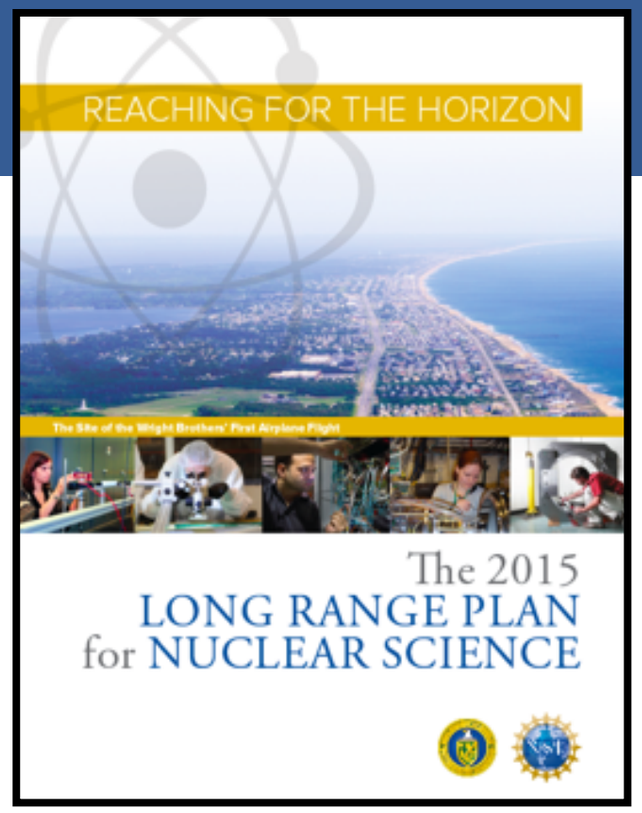
The excess of matter over antimatter in the universe is one of the most compelling mysteries in all of science. The observation of neutrinoless double beta decay in nuclei would immediately demonstrate that neutrinos are their own antiparticles and would have profound implications for our understanding of the matter-antimatter mystery.

We recommend the timely development and deployment of a U.S.-led ton-scale neutrinoless double beta decay experiment.

A ton-scale instrument designed to search for this as-yet unseen nuclear decay will provide the most powerful test of the particle-antiparticle nature of neutrinos ever performed. With recent experimental breakthroughs pioneered by U.S. physicists and the availability of deep underground laboratories, we are poised to make a major discovery.

This recommendation flows out of the targeted investments of the third bullet in Recommendation I. It must be part of a broader program that includes U.S. participation in complementary experimental efforts leveraging international investments together with enhanced theoretical efforts to enable full realization of this opportunity.

NSAC 2015 Long Range Plan



B: Initiative for Detector and Accelerator Research and Development

U.S. leadership in nuclear physics requires tools and techniques that are state-of-the-art or beyond. Targeted detector and accelerator R&D for the search for neutrinoless double beta decay and for the EIC is critical to ensure that these exciting scientific opportunities can be fully realized.

We recommend vigorous detector and accelerator R&D in support of the neutrinoless double beta decay program and the EIC.

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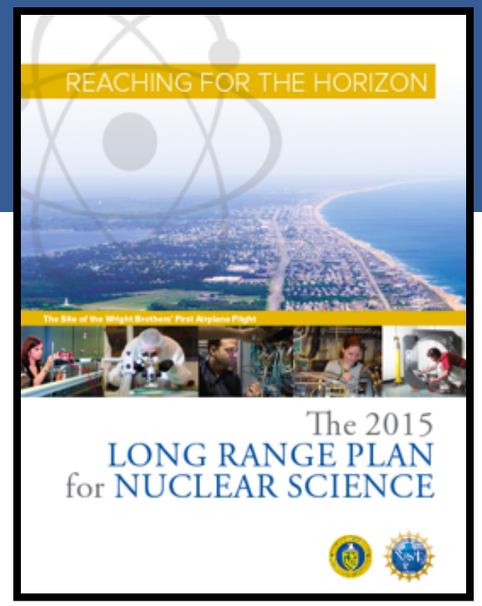
NSAC 2015 LPR Budgets



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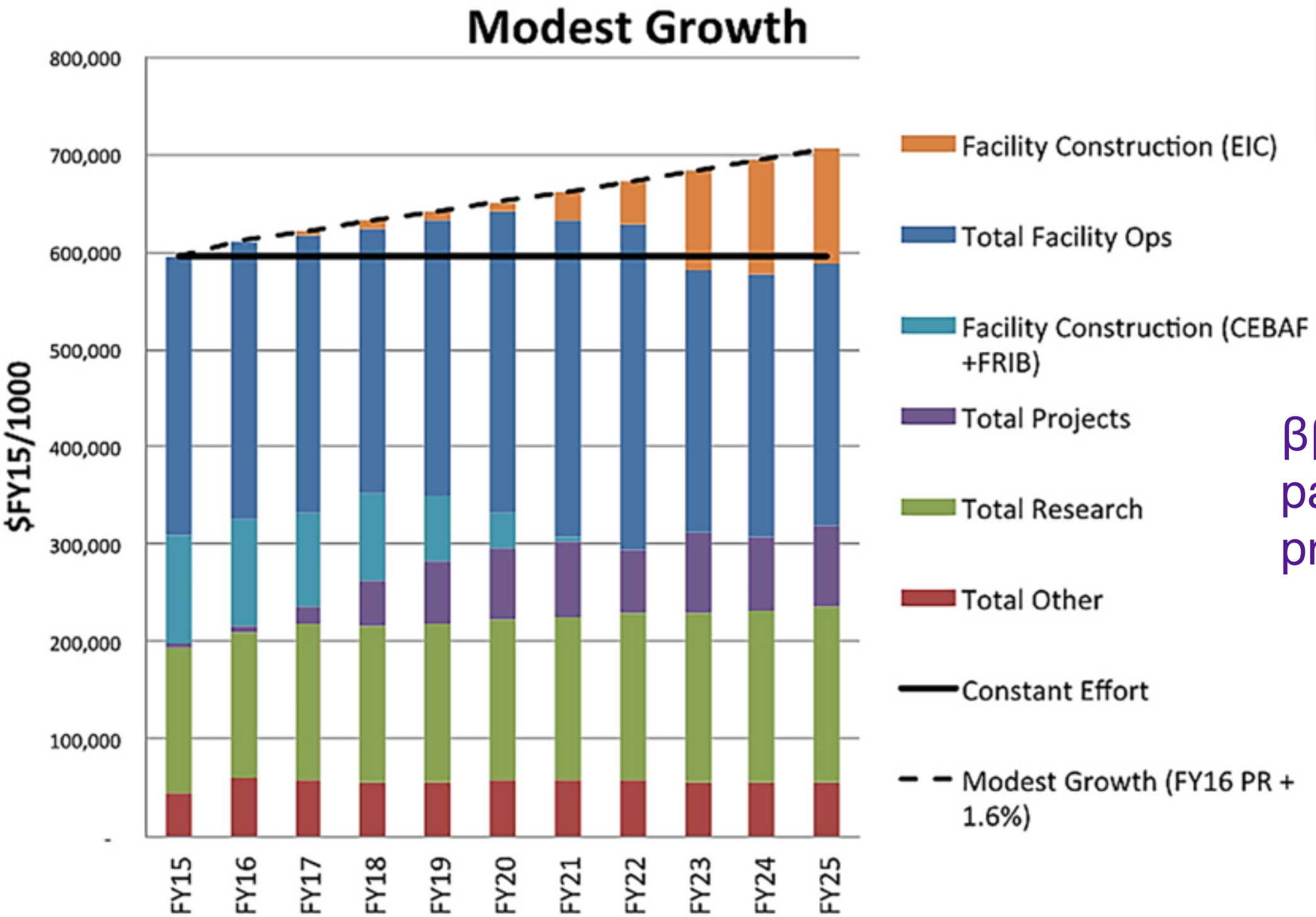
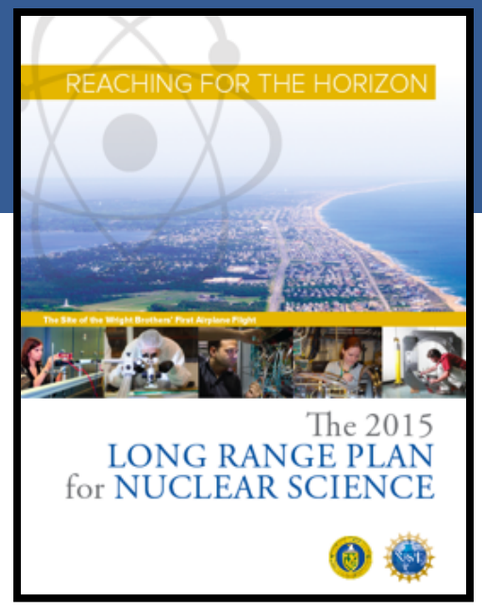
Note: General Estimate by cmt. - not binding



ββ-decay is part of projects

NSAC 2015 LPR Budgets ββ-Decay



"A program of U.S. leadership in the flagship experiment, participation in complementary experimental efforts that leverage international investments, and enhancement of the theoretical efforts required for the interpretation of these measurements will enable full realization of this unique opportunity to make a fundamental advance in understanding the most basic components of the universe.

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The ***down-select process is currently expected to be completed within three years****, at which point the optimum U.S. strategy towards a ton-scale experiment will have been identified.* ***Construction of this flagship experiment is expected to require five years, with capital investment peaking at about $50M/year during this period.*** *This profile increases in the last few years of FRIB construction, when construction funding for that project is decreasing."*

Considerations towards a ton scale 0νββ

Nuclear Science Advisory Committee (NSAC) — committee of nuclear scientists that advises the Federal agencies involved in nuclear physics — the Department of Energy (DOE) Office of Nuclear Physics and the National Science Foundation (NSF)

In 2013 NSAC established a standing sub-committee on Neutrinoless Double Beta Decay (NLDBD).

- The committee issued its first report in April 2014.
- On October 15, 2015 the committee presented an update on R&D for the ton scale.

See: http://science.energy.gov/np/nsac/meetings/

NSAC NLDBD 2014 "Guidelines"

The Subcommittee recommends the following guidelines be used in the development and consideration of future proposals for the next generation experiments:

1.) Discovery potential: Favor approaches that have a credible path toward reaching 3σ sensitivity to the effective Majorana neutrino mass parameter mββ=15 meV within 10 years of counting, assuming the lower matrix element values among viable nuclear structure model calculations.

2.) Staging: Given the risks and level of resources required, support for one or more intermediate stages along the maximum discovery potential path may be the optimal approach.

3.) Standard of proof: Each next-generation experiment worldwide must be capable of providing, on its own, compelling evidence of the validity of a possible non-null signal.

NSAC NLDBD 2014 "Guidelines"

4.) Continuing R&D: The demands on background reduction are so stringent that modest scope demonstration projects for promising new approaches to background suppression or sensitivity enhancement should be pursued with high priority, in parallel with or in combination with ongoing NLDBD searches.

5.) International Collaboration: Given the desirability of establishing a signal in multiple isotopes and the likely cost of these experiments, it is important to coordinate with other countries and funding agencies to develop an international approach

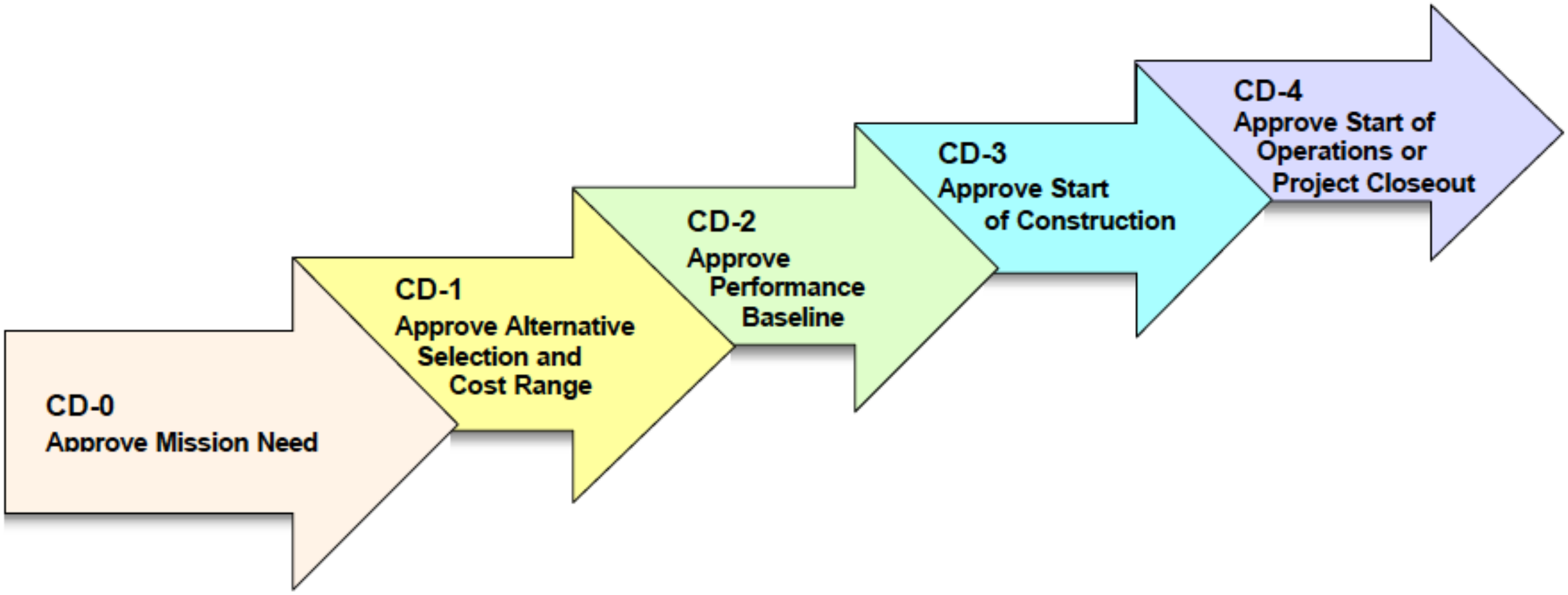
6.) Timeliness: It is desirable to push for results from at least the first stage of a next-generation effort on time scales competitive with other international double beta decay efforts and with independent experiments aiming to pin down the neutrino mass hierarchy.

REPORT TO THE NUCLEAR SCIENCE ADVISORY COMMITTEE Neutrinoless Double Beta Decay APRIL 24, 2014

U.S. Process and Schedule Overview

- In terms of funds, the DOE ONP will be the lead agency.
  - NSF will likely participate, but at a lower level of support.
- DOE and NSF expect international contributions at a level proportional to participation.
  - DOE would like to initiate conversations with agencies in other countries very soon. (request for contacts from DOE)
- In October 2015, statement from NSAC NLDBD subcommittee was a down-select would occur in 2-3 years ⇒ 2018 or 2019.
- Within U.S., DOE will manage the project via strict management protocol - DOE Order 413.3B
  - "Line item" in federal budget (Exec. & Legislative oversight)
  - Lots of "hoops" to jump through via 413.3B
  - National Laboratory must manage the project

DOE 413.3 & Critical Decision Process



Typically requires 12-18 months between most steps

DOE CD Process / Documents

CD-1

- Acquisition Strategy
- Conceptual Design Report
- Risk Management Plan
- Risk Assessment
- Preliminary PEP,
- Preliminary Hazard Analysis (HA),
- Preliminary Security Vulnerability Assessment Report (SVAR)
- Initial Cyber Security Plan for IT projects.
- QA Program Documentation

CD-2

- Performance Baseline
- Preliminary Design
- Updated Risk Assessment
- Updated PEP
- Updated HA (Approved at Field Level)
- Updated Preliminary SVAR
- NEPA Documentation
- Updated Initial Cyber Security Plan for IT projects

CD-3

- Final Design
- Updated CD-2 documents
- Updated QA Program
- An Approved Construction Project Safety & Health Plan
- Updated Cyber Security Plan for IT projects

0νββ Prospect and Process

- U.S. Nuclear Physics community and agencies are committed to a strong 0νββ program.
  - Flagship U.S. led experiment
  - Participation in other international 0νββ experiments
- International collaboration is required and will require cooperation not only amongst collaborators but coordination between funding agencies.
  - Time scales - U.S. down select in ~2018.
  - Project funds from 2018 - 2025
- Down-select will be a rigorous scientific process.
  - Ge is clearly a viable option.
  - Requires substantial commitment and work over the next several years.