The Majorana $0\nu\beta\beta$ Experiment

The Majorana Experiment will perform an essentially background-free measurement of neutrinoless double-beta decay ($0\nu\beta\beta$) in 120 kg of ^{76}Ge with the goal of determining the neutrino mass.

BACKGROUND

Neutrinoless double-beta decay provides the physics community with the opportunity to build on our successes in understanding the neutrino and crafting a new standard model. With the results from Super-Kamiokande, SNO, KamLAND, and other neutrino experiments we have demonstrated that neutrinos are massive, change flavor, and play an important role in the universe. These results have yielded the first physics beyond the standard model in nearly four decades. Even with these impressive results, neutrinos continue to provide some of the most exciting opportunities in understanding our universe. Theoretical prejudices for Majorana neutrinos have existed for decades and neutrinoless double-beta decay is the only practical technique that can determine whether neutrinos are Majorana or Dirac particles.

For the first time we can mount experiments that probe the neutrino-mass region below the upper limits set by direct kinematical searches (tritium decay) and suggested by observational cosmology, while planning scaled approaches that can address the lower bounds of mass defined by the atmospheric and solar plus reactor neutrino oscillation experiments.

Measuring the absolute mass of neutrinos and determining their Majorana nature are two of the most important goals of the physics community today. We propose here a plan and process for achieving these goals.

OBJECTIVES

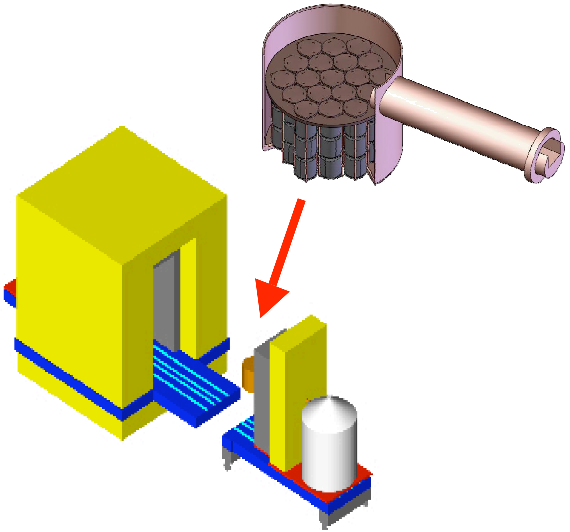
The objective of the first experimental phase of Majorana is to build a 120-kg array of high-purity Ge, enriched to 86% in ^{76}Ge, to search for $0\nu\beta\beta$ decay. The physics goals for this first phase are to:

- Probe the quasi-degenerate neutrino mass region above 100 meV within a reasonable time frame (5 years), which will equal or surpass other current international efforts.
- Demonstrate that backgrounds at or below 1 count/ton/year in the 4-keV region of interest around the $0\nu\beta\beta$-decay peak (1 count/ROI/t-y) can be achieved that would justify scaling up to a 1 ton or larger mass detector.
- Definitively test the Klapdor-Kleingrothaus claim of an observation of $0\nu\beta\beta$ decay in ^{76}Ge in the mass region around 400 meV.

These goals are consistent with the various studies that have emphasized the need to study $0\nu\beta\beta$ decay in different isotopes and with different experimental techniques.

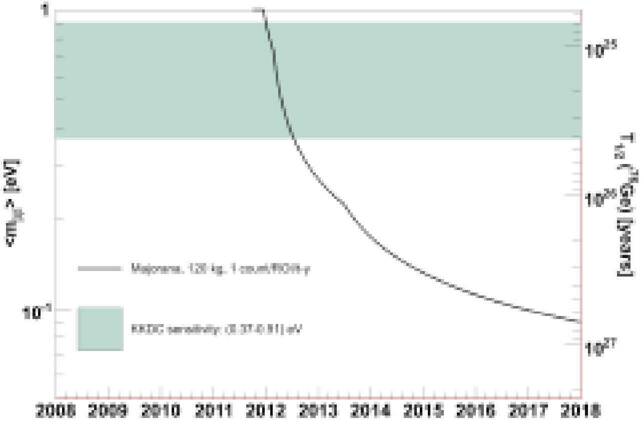
TECHNICAL APPROACH

The proposed method uses the well-established technique of searching for $0\nu\beta\beta$ decay in high purity Ge-diode radiation detectors that play both roles of source and detector. The technique is augmented with recent improvements in signal processing and detector design, and advances in controlling intrinsic and external backgrounds. Progress in signal processing from segmented Ge diode detectors potentially offers significant benefits in rejecting backgrounds, reducing sensitivity of the experiment to backgrounds, and providing additional handles on both signals and backgrounds through multi-dimensional event reconstruction. Development of sophisticated copper electroforming methods allow the fabrication of ultra-low-background materials required for the construction of next-generation experiments. It is important to note that Ge-based detectors are the only next generation $0\nu\beta\beta$ experiments that are currently proposing to perform near background-free measurements in



the 0νββ-decay peak region of interest. This will be a critical factor in convincing the community of the validity of any future result that claims to observe this rare decay mode.

The initial Majorana experiment will consist of 114 ^{76}Ge crystals in the form of high-resolution intrinsic germanium detectors, deployed in two 57-crystal modules, located deep underground within a low-background shielding environment. This represents more than an order-of-magnitude increase in the mass of enriched isotope over previous generation Ge-based experiments. The justification for a detector mass size of 120 kg is directly linked to all three of the physics goals listed above.



The Majorana experiment will have much lower background and substantially higher statistical significance than other efforts.

Observation of a sharp peak at the 0νββ endpoint would quantify the 0νββ-decay rate, demonstrate that neutrinos are Majorana particles, indicate that lepton number is not conserved, and provide a measure of the effective Majorana mass of the electron neutrino. Majorana will either conclusively establish the Klapdor-Kleingrothaus claim of 0νββ-decay, discover a Majorana mass below Klapdor-Kleingrothaus's sensitivity, or will significantly improve the lower limits on the decay lifetime from the current level of about $2x10^{25}$ years to about $7x10^{26}$ years, corresponding to an upper limit of 90 meV on the effective Majorana electron-neutrino mass.

COLLABORATION

The Majorana Scientific Collaboration consists of about 100 scientists and 16 collaborating institutions from four countries, with extensive experience in double-beta decay and ultra-low-background experiments. The scientific and technical experience of this team is ideally matched to the experimental requirements and the team is strongly motivated by the opportunity to address very fundamental scientific questions. The excitement that this challenge offers is reflected in the very high quality of graduate students, postdocs, and young faculty that we have been able to attract to the collaboration.

SUMMARY

Neutrinoless double-beta decay experiments have the potential to dramatically alter our understanding of neutrinos, fundamental interactions, and the role neutrinos play in the universe. Majorana offers an opportunity to lead this quest with an experiment deployed in North America.

John Wilkerson, Spokesperson
Telephone: (206) 685-9061
Email: jfw@u.washington.edu
