MOON: A Next Generation Double Beta Decay and Solar Neutrino Experiment
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1. Motivation
Over the past thirty years, experimental evidence has pointed scientists to the fact that neutrinos, once considered massless particles, exhibit a phenomenon known as neutrino oscillations, which implies that they possess non-zero masses. This realization comes from not one single observation, but a body of evidence gathered from solar, atmospheric, and reactor neutrino experiments. The goal of the next generation of neutrino experiments is to probe deeper into understanding the very nature of neutrino masses and mixings.

One of the goals for future experiments is to address the nature of the neutrino mass. It is possible that neutrinos are what are called Majorca particles, where the neutrino and antineutrino are the same particle. Such an observation will have a great impact on our theoretical understanding of neutrinos.

A second goal for future experiments to address is the absolute impact on our theoretical understanding of neutrinos. Are the same particle. Such an observation will have a great impact on astrophysics and cosmology.

Finally, a third goal for future experiments is to gain greater precision on the neutrino oscillation parameters. Knowing more precisely how neutrinos mix will shed new light on the nature of the weak force and on physics beyond the Standard Model.

2. Three Experiments in One
The MOON experiment, Molybdenum Observatory of Neutrinos, is a next generation neutrino experiment with the capability of addressing major open questions within a single detector.

The MOON experiment uses Mo as an active target that is sensitive to low energy oscillations. Firstly, the Mo target provides an ideal setting to studying double beta and neutrinoless double beta decay. The experiment is sensitive to neutrinoless double beta decay via the 0\(\nu\)\(\beta\beta\) decay to the ground state, and excited states of \(^{100}\text{Ru}\).

Secondly, MOON is sensitive to low energy solar neutrinos. The latter reaction, though suppressed by a factor of 40, provides a 4 -fold coincidence signature, making it an ideal setting to studying double beta and neutrinoless double beta decay. MOON also shows a mass sensitivity to changes in solar neutrino oscillations.

Finally, because of the low energy threshold, the MOON experiment is sensitive to low energy neutrino reactions. MOON uses a 3-ton active target that is sensitive to low energy neutrino reactions. MOON can also serve as monitor for neutrinos emitted during a supernova explosion.

3. Solar Neutrinos
The MOON experiment is sensitive to low energy solar neutrinos via the charged current reaction:

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\nu_e + {^{100}\text{Mo}} \rightarrow {^{76}\text{Ge}} + e^+ + \nu_e
\]

This reaction has a threshold of 168 keV and can be tagged via the irreducible \(2\nu\beta\beta\) decay to \(^{100}\text{Ru}\). The low threshold allows one to measure both the \(2\nu\) and \(0\nu\) channels simultaneously. This is done via cryogenic detectors, which are very sensitive to neutrino oscillations. Neutral current reactions, such as \(0\nu\beta\beta\), might be better suited to studying neutrino oscillations.

4. Double Beta Decay
In addition to solar neutrinos, the \(1\text{.Mo}\) target has an allowed \(1\text{.Mo}\) reaction, which is also sensitive to \(0\nu\beta\beta\). At the latter reaction threshold, not only does it provide a \(0\nu\beta\beta\) reaction that is of importance to neutrino physics, since it can shed light on the nature of the weak force and on physics beyond the Standard Model.

5. Scintillator Technology
One technological approach in constructing the MOON detector is to use plastic scintillator to measure the position and energy of electrons produced from solar and \(1\nu\beta\beta\) decay signals. This technology takes advantage of the spatial and temporal correlation to separate signal from backgrounds.

Under this configuration, the detector would consist of thin molybdenum foils sandwiched between scintillating layers which would measure the energy of the event. The layers would measure 2 mm x 2 mm x 5 mm, while the plastic scintillator plates would measure 2 m x 2 m x 0.5 mm. Tests with ELEGANT V show that by using avalanche type sensors can yield a final energy resolution of 1.5% at 3 MeV (4.4% with the Mo plate).

6. Bolometry
Another technological approach that is currently under study is using cryogenic detectors. Such an approach is especially suited for \(0\nu\beta\beta\) measurements, where good energy resolution is essential in separating the signal from the irreducible \(2\nu\beta\beta\) background.

As molybdenum is a superconductor with \(T_c \approx 2.5\) K, it is a good candidate to be used as an active cryogenic detector. Equilibration between broken pairs and lattice, however, are very slow. Therefore, non-magnetic compounds such as Mo, might be better suited to this application.