Double Beta Decay Working Group White Paper
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## I. INTRODUCTION

Neutrinoless Double-beta decay ($0\ \nu\ \beta\beta$-decay) is an important probe for physics beyond the standard model, as it is perhaps the most sensitive probe of neutrino mass and character. The interest in, and the relevance of, next-generation $0\ \nu\ \beta\beta$-decay experiments is increasing, with nonzero neutrino mass strongly suggested by the Super Kamiokande and SNO neutrino oscillation results. But oscillation experiments are only sensitive to the relative mass scale or $\delta m^2$ and not the absolute mass scale. Even so, these results indicate that at least one neutrino has a mass greater than 50 meV, that is, for at least one neutrino $m_\nu^2 > \delta m^2_{\rm atmos}$. Double beta decay experiments are sensitive an effective neutrino mass $< m_\nu >$ that is comparable to mn. Furthermore, such experiments remain the only way to establish the Dirac or Majorana nature of neutrinos. Indeed, the "black-box" theorem shows that in the context of most gauge theories, the observation of $0\ \nu\ \beta\beta$-decay imply the existence of a massive Majorana neutrino eigenstate. A number of experiments aiming for sensitivities for $< m_\nu >< 50$ meV are being proposed. Many of these experiments are aided by two major opportunities of our time: The development of a National Underground Science Laboratory (NUSL), and the end of the cold war, allowing collaboration with former Russian Federation isotopic enrichment facilities. We find the physics of $0\ \nu\ \beta\beta$-decay very compelling and the future opportunities exciting.

## II. THE REPRESENTATIVE EXPERIMENTS

The following experiments summarized in the Table were described at the NUSL Conference Double-Beta Decay Working Group. Several of these consider the NUSL a potential site. The various needs for these experiments do not differ greatly. Accordingly we consider three of these as representative of $\nu\ \beta\beta$-decay experiments that might be sited at NUSL. We describe the needs of these three as typical cases. These experimental proposals are generally known to the community, so only a brief description of each is given here.

- Majorana
  A large array of germanium spectrometers, this experiment typifies the "compact active target" class of experiment.

- EXO
  Utilizing a gaseous or a liquid Xe target and sensitive daughter extraction techniques, this experiment typifies the "active liquid cryogen" class of experiment.

- MOON
  With many thin foils of active material observed by interleaved sheets of scintillator, this typifies the "separate source and detector" class of experiment.

| Experiment | Source | Technique | Contact |
|---|---|---|---|
| CAMEO | Cd | Cd crystals in liq. Scint. | M. Giammarchi |
| CANDLES | Ca | CaF2 scintilattors | T. Kishimoto |
| CUORE | Te | TeO2 bolometers | E. Fiorini |
| EXO | Xe | time projection chamber | G. Gratta |
| Majorana | Ge | HPGe crystal detectors | H. Miley |
| MOON | Mo | Foil-Scintillator sandwich | H. Ejiri |
| NEMO | Var. | Foil-tracking chamber sandwich | S. Sutton |

## III. TYPICAL SPACE REQUIREMENTS

Each of the representative experiments was asked to define their space requirements at NUSL. The following summarizes this information, with dimensions appearing as length $\times$ width $\times$ height.

- Majorana $5 \times 4 \times 3$ m$^3$ apparatus, $4 \times 4 \times 3$ m$^3$ control systems.
- EXO $5 \times 5 \times 5$ m$^3$ apparatus, $5 \times 4 \times 3$ m$^3$ control systems, $4 \times 4 \times 3$ m$^3$ cryogenic purification systems.
- MOON $5 \times 8 \times 5$ m$^3$ apparatus $8 \times 11 \times 6$ m$^3$ lab area and control systems.

## IV. COMMON CHARACTERISTICS

Most $0\ \nu\ \beta\beta$-decay experiments have rather modest site requirements. Key features are modest footprints, power, and cooling requirements.

- Most experiments require only 10-25 kW.
- All experiments benefit from stable temperatures.
- Most want 20 C or less, AC will be required.

## V. BACKGROUNDS AND INFRASTRUCTURE

To reach the desired sensitivity, $0\ \nu\ \beta\beta$-decay experiments require carefully-controlled background levels. Site requirements related to background vary by background type:

- **$\gamma$, low-energy n:** These can be effectively shielded for proposed locations with conventional moderator and shielding techniques.
- **Fast Neutrons from muon production:** There is not much flux information available at higher energies. Depth or exotic shielding are required to limit this background.

- **Radon**
  - All experiments would like scrubbed air, with residual radon levels of $< 1$ Bq/m$^3$.
  - Most experiments have a critical volume needing to be completely purged of radon. The use of pure nitrogen purge gas is a common technique. Radon-free liquid nitrogen or nitrogen gas may be required for this purpose. Boil-off $N_2$ gas from liquid nitrogen is used in most cases.

## VI. SPECIAL FACILITIES (JOINT OR SHARED)

Certain facilities are needed by all the representative experiments and are good candidates for general infrastructure projects. These include:

- Clean-room for prep/assembly/cleaning,
- DI water system,
- Cranes for assembly and manipulation of detector and shielding elements,
- Radon-free material storage area,
- Machine shop, both general and for ultra-low background work,
- Low-level counting capabilities for materials screening,

## VII. SPECIAL FACILITIES (EXPERIMENT SPECIFIC)

Some experiments rely on particular technology requiring special infrastructure. Examples are:

**Majorana**

- An underground Cu electroforming facility,
- Underground Ge crystal growth and detector preparation is a possibility.

**EXO**

- Large-volume liquid Xe containment,
- Continuous cryogenic purification system.

## VIII. NEAR-TERM SCHEDULES

**Majorana**
Will need a underground location this winter for prototype.
**EXO**
Will site prototype in late 2002
**MOON**
Near-term R & D will be above ground.

## IX. SAFETY

All experiments using nitrogen purge gas may require ambient air oxygen-level monitoring and attention to ventilation. Several of the experiments have unique safety issues:

**Majorana**

Acids and plating baths used in copper electroforming.

**EXO**

Large quantities of liquid cryogens present oxygen displacement hazard.

## X. SUMMARY

Considering the recent results of neutrino oscillation experiments, the possibility of a positive measurement of effective neutrino mass motivates the current generation of proposed 0n bb-decay experiments. These experiments will have active underground efforts in the near term.

There are a number of shared resources that would benefit all 0 $\nu$ $\beta\beta$-decay experiments sited at NUSL, and coordination between each of the R & D stages and full experiments could yield significant infrastructure synergies.