1. Experiment Summary

We propose to use the High Intensity Gamma-ray Source to measure the ionization signal produced by low-energy nuclear recoils in liquid argon. Measurements will be made using an argon dual-phase proportional scintillation counter that is currently being constructed at Lawrence Livermore National Laboratory in collaboration with Purdue University and University of California Berkeley. The detector is a small prototype, being built to understand the systematics of these detectors and quantify the ionization signal produced by low-energy nuclear recoils in liquid argon. The end goal of our effort is to observe coherent neutrino-nucleus scattering (CNS). Predicted in 1974 [1], CNS has eluded all experimental attempts at observation. Observing CNS would provide some confirmation of the neutrino theory in the Standard Model of Particle Physics, a model that has been strongly contested over the course of experimental neutrino research history. If it is shown the coherent neutrino-nucleus scattering does occur, then a CNS detector could be used to monitor nuclear power stations as well as measure total flux in neutrino basic science research (CNS is a flavor blind interaction).

The difficulty in detection is a combination of the small cross-section of neutrino interactions and the very low energy nuclear recoils it produces: the mean recoil energy of scattering caused by reactor anti-neutrinos is \(~250\) eV in argon. Past measurements of the ionization signal produced by nuclear recoils in liquid noble elements have used mono-energetic neutron beams to produce recoils via elastic scattering [2-4]. A majority of these measurements have been performed by the dark matter community, which is currently employing liquid and liquid/gas noble element detectors to search for WIMP-nucleus scattering. Elastic neutron scattering has been very successful at producing tagged nuclear recoils with energy in the few to tens of keV energy range, however, several limitations prevent extending measurements into the sub-keV domain with this technique.

We propose using nuclear resonance fluorescence, on sufficiently short-lived nuclear states (\(\Gamma \geq \sim1\text{eV}, \tau \leq \sim4\text{fs}\)), to produce sub-keV nuclear recoils. The energy of these recoils may be inferred with coincident detection of the fluoresced photon. Though knowledge of recoils accompanying photo-absorption and photo-emission has been well understood for decades, exploiting photonuclear interactions as a source of low-energy nuclear recoils is novel. A successful measurement would be significant advance in the study of low-energy nuclear recoils by extending the energy domain of measurements down by one to two orders of magnitude and pioneering this new technique as well as making significant contributions to the PhD thesis of Tenzing Joshi and Michael Foxe.