MONTE CARLO SIMULATIONS FOR DARK MATTER PARTICLE DETECTION IN LIQUID HELIUM-4

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Liquid ^{4}He has been recently theorized to be suitable for the detection of light-mass WIMPS, the leading candidate for dark matter. Its low atomic mass and certain atomic properties (e.g. at low temperatures, ^{4}He turns into a Bose-Einstein condensate with crystalline properties and kinematic quasiparticle thermal excitations) make it ideal for detecting WIMPS in the 1-10 GeV range. The primary objective of my work is to determine the effectiveness of a liquid ^{4}He detector by simulating signals and calculating the theoretical discrimination power, i.e. the difference between an electron recoil signal (non-dark matter collision) and a nuclear recoil signal (dark matter collision). I hypothesized that a cylindrical detector would not preserve initial location data due to random scattering, but would have large discrimination power due to magnification effects of quasiparticle excitations in Bose-Einstein condensates like supercooled liquid ^{4}He. The code for the simulation, written in Python, takes into account quasiparticle interactions with the sides of the container, at points of quantum evaporation, and at the bolometer sensor interface above the test chamber using theoretical equations derived from various research groups, and account for quasiparticle mode changes as well as energy and momentum transitions. The completed program, run on two separate supercomputer clusters, simulated 1 million quasiparticles at 18 momenta values and 6 starting locations inside the chamber. The data output from the simulated bolometer array was analyzed, then compared to the calculated initial conditions to isolate discrimination power between the two recoil signals and preserved initial location data. There was a clear temporal difference (~1.5 milliseconds) between the peak signal strengths for quasiparticles of different momenta. The strength of the signals was also strong (~1 x 10^{-19} Watts), as we originally hypothesized, and reached magnification levels more powerful than current detectors. However, we also discovered a focusing effect of the cylindrical container that resulted in an extremely accurate preservation of the initial X-Y location, data that is critical for investigating the properties of WIMPS in the event of a dark matter collision. This suggests that liquid ^{4}He is an ideal target medium for a direct dark matter detection experiment.