Project Cherenkov
- PHYS 512 Final Project -

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1 Context: The Experiments

Ultra-low background experiments, such as those searching for WIMP dark matter, or neutrinoless double beta decay, search for energy deposits resulting from nuclear recoil scattering on a target nucleus by a GeV mass particle, e.g. [1], or a distinct peak at the end of a beta decay energy spectrum respectively, e.g. [2]. Many of these detectors are placed deep underground in order to shield them from cosmic backgrounds such as: protons, light nuclei, and muons. Unfortunately, even with several kilometers of rock overburden in the deepest of mines, there is still a residual muon flux that remains. These muons have energies in the several hundred GeV range, and can create spallation products as they interact with nuclei in the rock on their way down [3]. In this way, high energy neutrons are created that can traverse the shielding that surrounds many of these low background detectors and enter the experiment's signal region. These neutrons can either scatter off of nuclei producing WIMP-like nuclear recoil signals, or capture in the detector creating background beta emitters that can mimic a neutrinoless double beta signal. In either case, understanding the neutron production, and tagging these traversing muons can reduce the contribution of the cosmogenic neutron background to the experiments significantly. Many experiments opt to employ a water-cherenkov active muon veto. As the high energy muons passes through the water surrounding the detector they produce cherenkov light which carries directional information. Recent studies have shown that the direction of the resulting neutrons closely follow that of the muons [4]. Thus, optimizing a detector to not only tag muons but also reconstruct their tracks is interesting for the field.

The trouble arises when, traditionally, simulating these muons in Geant4 (dedicated particle tracking monte carlo software) can take ages to propagate thousands to millions of photons onto detector walls. Thus, the optimization of photosensor placement can take quite a while. This project will attempt to address the problem under various simplifications. Approximations will be made and, hopefully, will result in a fast-turn around photon propagation code (if done correctly!).

2 Project Setup

For simplicity we assume that the water tank is cylindrical, large (10 m) in diameter and height, and placed at SNOLAB in Sudbury, Ontario - a popular, and growing, laboratory for these sorts of experiments with the second lowest underground muon flux in the world [5]. We assume that a cryostat/inner detector is placed in a spherical volume that is concentric with the water shield.

References

[1] Z. Ahmed, D. Akerib, S. Arrenberg, M. Attisha, C. Bailey, L. Baudis, D. Bauer, J. Beaty, P. Brink, T. Bruch, *et al.*, "Search for weakly interacting massive particles with the first five-tower data from the cryogenic dark matter search at the soudan underground laboratory," *Physical Review Letters*, vol. 102, no. 1, p. 011301, 2009.

[2] J. Albert, D. Auty, P. Barbeau, E. Beauchamp, D. Beck, V. Belov, C. Benitez-Medina, J. Bonatt, M. Breidenbach, T. Brunner, *et al.*, "Search for majorana neutrinos with the first two years of exo-200 data," *Nature*, vol. 510, no. 7504, p. 229, 2014.

[3] D.-M. Mei and A. Hime, "Muon-induced background study for underground laboratories," *Physical Review D*, vol. 73, no. 5, p. 053004, 2006.

[4] B. Aharmim, S. Ahmed, A. Anthony, N. Barros, E. Beier, A. Bellerive, B. Beltran, M. Bergevin, S. Biller, R. Bonventre, *et al.*, "Cosmogenic neutron production at the sudbury neutrino observatory," *arXiv preprint arXiv:1909.11728*, 2019.

[5] B. Aharmim, S. Ahmed, T. Andersen, A. Anthony, N. Barros, E. Beier, A. Bellerive, B. Beltran, M. Bergevin, S. Biller, *et al.*, "Measurement of the cosmic ray and neutrino-induced muon flux at the sudbury neutrino observatory," *Physical Review D*, vol. 80, no. 1, p. 012001, 2009.