Chapter 10
Conclusions

This thesis has explored the use of PMT hit patterns in time and space for reconstruction and particle identification in liquid scintillator, as well as the application of Bayesian methods to $0\nu\beta\beta$ signal extraction.

Using Hamiltonian Markov Chain Monte Carlo, two dimensional fits in event energy and radius were employed, to predict a SNO+ $0\nu\beta\beta$ half-life sensitivity of $T_{1/2}^{\beta\beta} > 1.76 \times 10^{26}$ yr, at 90% confidence, after a three year live-time.

$\beta^{\pm}\gamma$ events produced by radioactive decay in the scintillator were shown to have non-point-like timing distributions, produced by the multi-site deposition of Compton scattering γ and the time delay caused by ortho-positronium formation. This characteristic signature was used to differentiate internal backgrounds from point-like $0\nu\beta\beta$ events using pulse shape discrimination (PSD) parameters. In particular, a PSD parameter, designed to separate $0\nu\beta\beta$ from poorly constrained ^{60}Co decay, was used to improve the 3σ $m_{\beta\beta}$ discovery level from 191 meV, which is already ruled out by Kamland-Zen, to 90.5 meV, which is allowed by all experiments.

Similarly, 40–60% rejection of each of the dominant external backgrounds inside $r < 4.2$ m was demonstrated using PSD, without significant sacrifice. For these backgrounds, improved rejection was achieved by accounting for the timing correlations and the angular hit distribution of the external backgrounds.

Finally, using a simulation of a next-generation slow-scintillator detector, equipped with a high coverage of high quantum efficiency, fast PMTs, it was shown that the angular distribution of Cherenkov light and the timing distribution of scintillation light can be used to reconstruct the position, time and direction of electrons. This information can be used to reject the ^{8}B elastic scattering background, improving the $m_{\beta\beta}$ sensitivity of a ^{8}B dominated experiment by 50%, and, in principle, to determine the underlying mechanism of $0\nu\beta\beta$.

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