Possible usage of Cherenkov photons to reduce the background in a ^{136}Xe neutrinoless double-beta decay experiment

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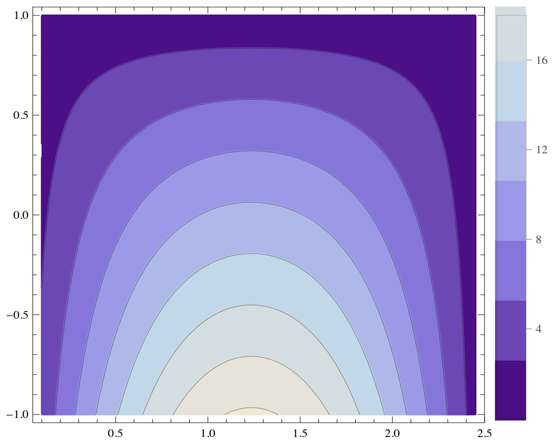
The main background to ^{136}Xe nutrinoless double-beta decay ($0\nu\beta\beta$) is the signal from Compton scattering of photons with energy around the decay end point at 2.458 MeV.

This can be reduced by self-shielding. Another proposed method is tagging the daughter barium nucleus. This is an extremely challenging task and, although feasible, presently suffers from very low efficiency.

Xenon scintillates at 178 nm (VUV) but liquid xenon is extremely transparent to ultra violet light.

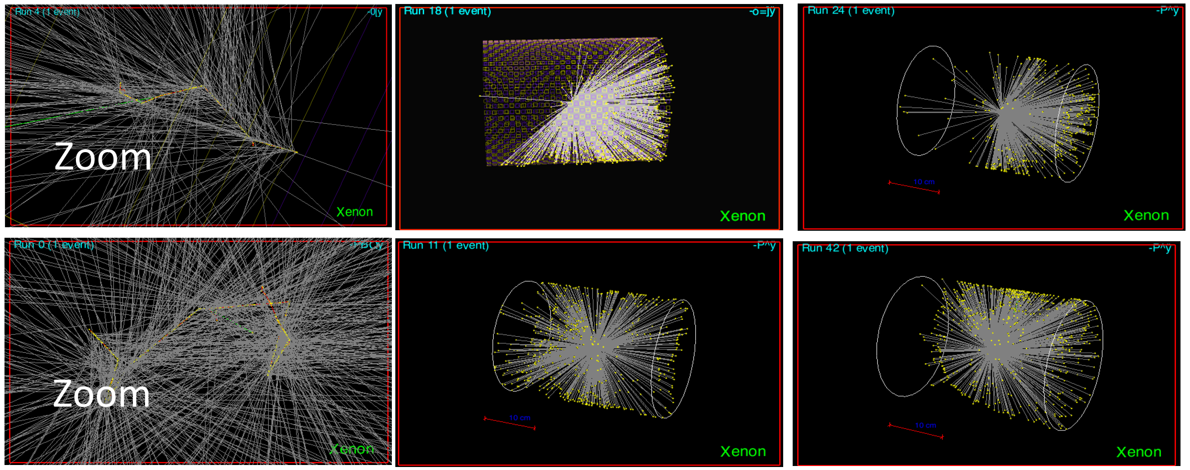
We studied the possibility to distinguish 1-electron Compton background from 2-electron $0\nu\beta\beta$ by combining scintillation and Cherenkov light amount (2 electrons go below threshold faster) and topology (two electron events are more symmetric).

The energy-angle distribution of the $0\nu\beta\beta$pair peaks at Q/2 and 180°

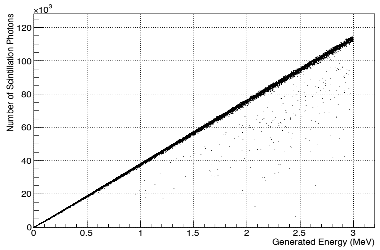


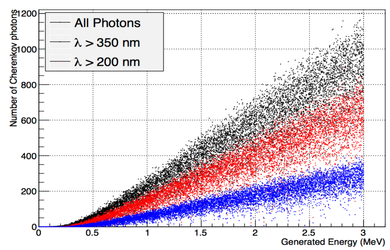
One electron event

Two Electrons event

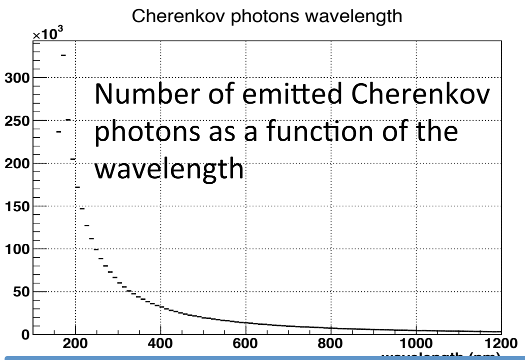


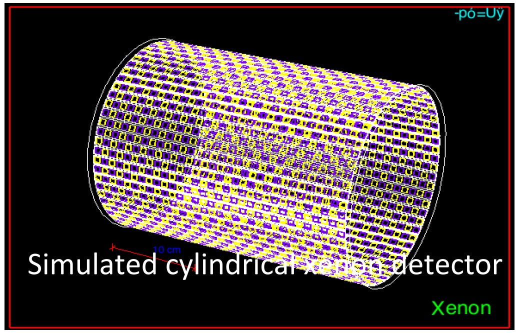
Scintillation yield and Cherenkov yield with different detector wavelength threshold. Cherenkov light is much less but can be enhanced by integrating only prompt photons

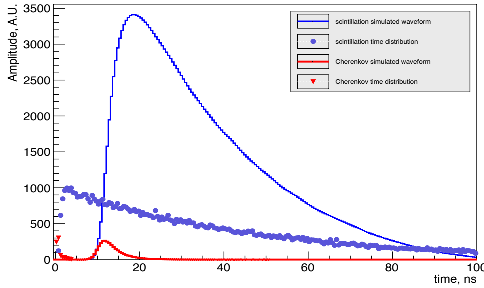




A simple simulation of a cylindrical detector read out by alternating SiPM sensitive to scintillation or cherenkov light only show that in a 2D plane one electron and two electron events cluster in different regions.



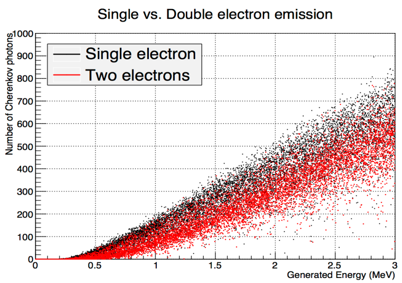


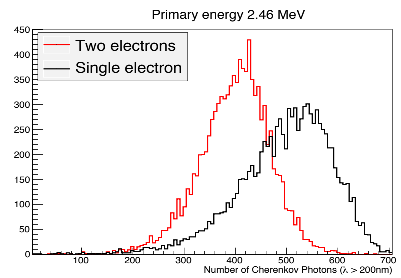


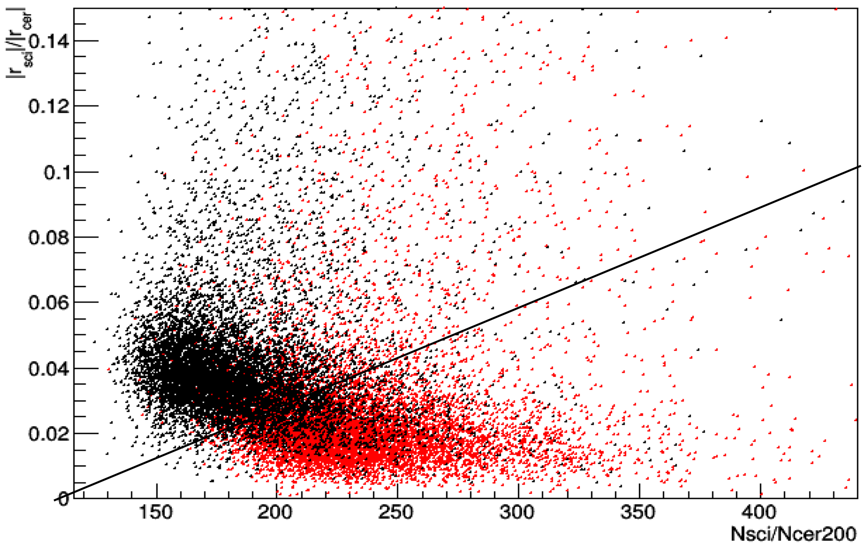
Simulation of Cherenkov (red) and scintillation (blue) light time structure before and after being detected by a SiPM

Cherenkov vs scintillation yield and topology

The plots below show the difference in Cherenkov light yield above 200 nm for one and two electrons cases. In the 2D plot a simple topological variable (the ratio of the centroid of Cherenkov vs scintillation light) is plotted against the ratio of scintillation/Cherenkov emitted photons. It is clear that a cut in this plane is effective in distinguishing the signal from the background.







The background from a single site Compton electron has both more Cherenkov light and a less symmetric shape.

The cut in figure, for instance, retains 75% of the signal events by rejecting 90% of the background