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Pulse-Shape Discrimination for Low-Background Proportional Counting

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Digital pulse-shape discrimination (PSD) is used to improve measurement sensitivity for internal-source gas proportional counters. Because the design of these detectors can be physically simple, they are well-suited for low-background applications where the radiopurity of detector materials must be stringently controlled. After mitigating dominant backgrounds (cosmic rays, external gamma-rays, radioactivity in materials), remaining background events frequently do not arise from ionization of the proportional counter gas. Various PSD methods have exploited the resulting pulse-shape differences. More sophisticated methods can offer better discrimination but may lead to more difficult calibration between model and detector. Variations between modeled and experimental shapes can limit the discriminating power achieved. This work addresses this difficulty by generating a template shape from each individual sample measurement of interest, a "self-calibrating" template. Differences in event topology can also cause differences in pulse shape. In this work the temporal region analyzed is limited to maximize background discrimination while avoiding unwanted sensitivity to event topology. Low-background measurements of tritium, carbon-14, argon-37, and argon-39 are currently being developed at the Pacific Northwest National Laboratory with detectors employing radiopure materials developed for neutrinoless double-beta decay and dark matter searches. The application of self-calibrating template PSD to measurement of these radioisotopes, along with initial measurement results, is described. Applications such as nuclear treaty verification, elucidating the environmental carbon cycle, and the assay of low-background materials for next-generation nuclear physics experiments are presented.