Analysis of low-level neutron measurements with ^{3}He spherical proportional counters

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Low-level neutron measurements are required in various fields of research. For example, there is interest in measuring the neutron flux at underground laboratories where experiments that search for rare events (e.g., dark matter) are carried out because neutrons can be one of the main contributors to the background for such experiments. Low-level neutron measurements are also needed to determine the neutron contamination of gamma sources that are used to calibrate the detectors used to search for rare events.

When analyzing low-level neutron measurements, it is important to be able to distinguish the signal due to neutrons from any background term that may be present. This can be a challenging problem, especially when the contribution from the neutrons is small compared to the background. We have developed a Bayesian solution to this problem for the case of neutron measurements carried out with ^{3}He spherical proportional counters.

The background of the proportional counters used for neutron detection is due primarily to alpha-particles emitted by materials used to build the counter, electronic noise, and photons and muons. To determine this background, we carried out measurements in an underground laboratory at the Asse salt mine, located near Braunschweig, Germany, at a depth of 490 m. Under these conditions, the contribution due to cosmic ray neutrons is negligible and the measured counts are predominantly due to the background of the proportional counters. Further measurements were carried out at locations where a small contribution due to neutrons was expected: At the underground laboratory Felsenkeller, which is located in the Weisseritz valley near Dresden, Germany, at a depth of 47 m, and at the calibration facilities of the Physikalisch-Technische Bundesanstalt (PTB) in Braunschweig, Germany.

The analysis of the data was done using Bayesian parameter estimation. For the measurements in the underground laboratory at the Asse salt mine, we introduced a parameterized model of the pulse height spectrum that accounts for the different components of the background. The analysis of the other measurements was similar except that the parameterized model now included a component to account for the neutron signal. The result of this work is a method that allows parameter estimation for a very general parameterized function which describes the background of proportional counters in the presence of a low-level neutron signal and permits effective signal-background separation.