Accurate Experimental Assessment of Extreme Deadtime Conditions for Gamma-Ray Detection Systems

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Abstract. Detection of gamma rays is typically based on the counting of ionization events within a sensitive medium of a detector. The counting process is therefore a foundational part of the current understanding in the radiation detection field and as such it has been rigorously analyzed. An aspect that is inherent to our current means of measuring radiation is the loss of counts; a property that can be minimized but never eliminated. An accurate understanding of these count losses (the so called deadtime) is therefore important to any form of high-precision experimental work. One example is cyclic neutron activation analysis (CNAA) paired with a pneumatic tube system, which allows for the measurement of samples with very short half-lives. Measurement systems exposed to rapid CNAA experiments experience a wide range of deadtimes. Therefore, it is inevitable that the processed data will be heavily influenced by extreme deadtime values. In this work, several different statistical models were applied to list-mode data to estimate the system deadtimes. The first method is applied by the Lynx multi-channel analyzer (MCA), which utilizes the pulser method for the deadtime assessment. The second method is the two-source method where the photopeak count rate of the Co-60's 1,332 keV is recorded and compared for different measurements. The third method is the MCA CAEN DT5781's internal deadtime calculation, which is based on the statistics of missing counts during the system's busy time. The fourth method is our own method called Time Interval Characterization (TIC) based on the fitting of a statistical model to the time intervals between DT5781 counts. By treating high deadtime measurements as mixtures of different k-value distributions we can further push the fitting capabilities of the model. Using this approach, we can account for discrepancies between our theoretical understanding of the distributions and the experimental results up to 70% deadtime. It is possible to assess the deadtime of a gamma-ray detection system by only using the timing information from the list data stream. TIC allows for the retroactive analysis and identification of system's pulse shaping settings and deadtime effects for any list-mode data with timing information. The statistical fitting method also allows for deadtime analysis to be able to selectively assess the system's properties as a time dependent feature.