Development of a Capture-Gated Fast Neutron Detector with Pulse Shape Discrimination using Digital Pulse Processing

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Abstract

This study explores the use of digital pulse processing techniques for n/g pulse shape discrimination (PSD) in liquid scintillators, and the application of these techniques to a capture-gated fast neutron monitor developed using an enriched 10B-loaded liquid scintillator (BC523A). The motivation for this study has been to develop a computationally-fast digital PSD algorithm, which can be used to detect a weak neutron flux in the presence of a strong gamma ray background and to assess its suitability for use as a portable neutron monitor for fast neutron dosimetry.

BC523A can operate as a full-energy neutron spectrometer when used in the 'capture gated' mode, where a characteristic capture time is observed between the proton recoil and neutron capture pulses, thus producing a very clean signature for those fast neutrons which are completely moderated within the detector volume. The use of digital waveform capture of this double-pulse sequence is a powerful technique that allows acquiring both the time-stamped pulse amplitudes and the capture lifetime in a single data set. The capture-gated performance of a 105 cm^3 BC523A detector was investigated using fast neutrons from an Am-Be source. The measured mean neutron capture time in BC523A was 470±80 ns, which is a factor of 5 shorter than that reported for liquid scintillators loaded with natural boron.

Due to its limited neutron detection efficiency, an extension of this technique to a large volume (685 cm^3) BC523A was developed, and provided an efficiency increase by a factor of 7. The efficiency enhancement was modelled using MCNP-4C.

Good n/γ separation was obtained using digital PSD applied to BC523A. The PSD figureof- merit (FOM) was investigated for various organic scintillators, and compared between digital and analogue pulse processing techniques. The application of digital PSD to the capture-gate detection mode was investigated, as an additional method for suppression of gamma sensitivity.